



# **Guide to Site and Soil Description for Hazardous Waste Site Characterization**

## **Volume 1: Metals**



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**GUIDE TO SITE AND SOIL DESCRIPTION  
FOR HAZARDOUS WASTE SITE CHARACTERIZATION**

**VOLUME 1: METALS**

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## **NOTICE**

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## ABSTRACT

This guide is intended to assist field personnel who must identify, describe, and interpret the site and soil characteristics of hazardous waste sites where metals contamination is suspected or known. The guide is directed to regional project managers, on-scene coordinators and others who may need to apply the basic principles of soil science to a waste site environment but may not have a thorough knowledge of basic information and protocols for describing and characterizing contaminated soils, particularly those contaminated with metal species. The approach presented, including the knowledge frames of an expert system, will be unfamiliar to most site investigators. These frames are also the basis for components of the Environmental Sampling Expert System (ESES).

Site and soil characterization data are important components in developing the sampling plan for both field and laboratory, in preparing for field reconnaissance, and in conducting sampling and analysis activities. Consequently, it is important to consider and synthesize data from all available sources in developing site and soil descriptions. It is also important to design the site and soil characterization process to complement the intended use of the data (e.g., site characterization, health and safety, risk assessment, evaluation of remedial alternatives, and monitoring during remedial action). This guide provides a general discussion (Section 2) of the elements of a background review and an on-site examination of site and soil characteristics essential to meeting the needs of these different data uses. This general discussion is followed by a catalogue of individual site (Section 3) and soil (Section 4) characteristics (e.g., climate and weather, texture and structure, hydraulic conductivity, slope, soil microorganisms) that could be investigated during site characterization. For each entry, the guide describes possible conditions of the characteristic (e.g., high, moderate, or low; prominent, distinct, or faint) and methods for assigning these conditions. References that provide more detailed information are given for each characteristic. Extensive definitions are provided for describing contaminated sites and soils.

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## ABBREVIATIONS AND SYMBOLS

ASTM	American Society for Testing and Materials
CERCLA	Comprehensive Environmental Response Compensation and Liability Act, 1980 (Super-fund)
CFR	Code of Federal Regulations
DDRP	Direct/Delayed Response Project
DQO	Data Quality Objective
EIS	Environmental Impact Statement
EMSL-LV	Environmental Monitoring Systems Laboratory - Las Vegas
EP	Extraction Procedure - EPA
EPA	U.S. Environmental Protection Agency
ESES	Environmental Sampling Expert System
FIT	Field Investigation Team
HSWA	Hazardous and Solid Waste Amendments to RCRA of 1984
LESC	Lockheed Engineering & Sciences Company
NEIC	National Enforcement Investigations Center
NOAA	National Oceanic and Atmospheric Administration
NPDS	National Pollution Discharge Information System
OSC	On-Scene Coordinator
OSHA	Occupational Safety and Health Administration
PRP	Potentially Responsible Party
RCRA	Resource Conservation and Recovery Act, 1976; Final Amendment, 1988
RD/RA	Remedial Design/Remedial Action
RD	Remedial Design
RI/FS	Remedial Investigation/Feasibility Study
RPM	Remedial Project Manager
RPO	Regional Project (Program) Officer
RRT	Regional Response Team
SARA	Superfund Amendment and Reauthorization Act, 1986
SCS	U.S. Department of Agriculture, Soil Conservation Service
SM	Site Manager
SSS	Soil Survey Staff
SWDA	Soil Waste Disposal Act
USCS	Unified Soil Classification System
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
UST	Underground Storage Tank

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## **SECTION 1.0**

### **INTRODUCTION**

This guide or knowledge book is intended to assist personnel to identify, describe, and interpret the site and soil characteristics of hazardous waste sites, particularly where metals contamination of soils is suspected or known. It is directed toward both management and field personnel: Regional Project (Program) Officer (RPO), Remedial Project Manager (RPM), Site Manager (SM), On-Scene Coordinator (OSC), Field Investigation Team (FIT), Regional Response Team (RRT), Initial Entry Party (Team), Work Party, Environmental Response Team, the potentially responsible party (PRP), and others concerned with onsite investigations, site surveys and reconnaissance including some aspects of geological and geophysical reconnaissance and logging that deal primarily with soils. The guide is directed not only to personnel who are experienced field investigators but also to those who may need to learn and apply the basic principles of characterizing soils and their contaminants and the environment without having had formal training. For that reason, scientific terminology is defined in the text or in the glossary.

The approach presented will be unfamiliar to most investigators because it uses expert system-type knowledge frames (sets of specific descriptive information) to describe site and soil characteristics. See the glossary for a description of an expert system, knowledge frame, knowledge-based system tools, and inference engine.

Currently, the U.S. Environmental Protection Agency (EPA) does not have a standard procedure, guideline, or protocol for site description and soil characterization that addresses site and soil contamination with metal or metalloid species. In preparing this guide, new approaches within the expert system knowledge frame context for description and classification have been developed that emphasize questions and problems directed toward metal and metalloid contamination at hazardous waste sites. Various references have been consulted to compile a comprehensive "knowledge book." Standard procedures for site and soil description and classification developed by the U.S. Department of Agriculture Soil Conservation Service (SCS) are used or have been modified to suit CERCLA-RCRA field situations. SCS guidelines have previously been modified for EPA projects, such as the Direct/Delayed Response Project (DDRP) soil acid precipitation activities (Kern et al., 1988; USDA Soil Conservation Service, 1979).

The guide is organized as follows. Section 2 outlines general considerations and processes for collecting and using site and soils data. Sections 3 and 4 present detailed knowledge frames of the site and soil conditions most likely to be encountered in the field. A number of these conditions pertain to both the natural and contaminated environments. A references cited list; an appendix listing common sources of characterization data, soil and hydrogeologic parameters for characterization of contaminated soils; and an extensive glossary complete the guide. The glossary includes definitions of almost 900 technical and scientific terms used in the knowledge frames to define sites, soils, and

contaminants within the CERCLA-RCRA framework for hazardous waste site investigations. A soil description form and methods are included.

Users of this guide should be aware that the knowledge frames presented in Sections 3 and 4 are also the basis for the site and soil components for metals and metalloids of the Environmental Sampling Expert System (ESES) under development by the EPA Environmental Monitoring Systems Laboratory-Las Vegas (EMSL-LV) through EMSL-LV's prime contractor, Lockheed Engineering & Sciences Company (LESC). The format of the knowledge frames is designed primarily for use with the ESES, but the frames should also provide a logical and consistent reference for those who intend to use this knowledge book alone or in association with the Field Pocket Guide (Boulding, 1991). Because users of this knowledge book are likely to be the eventual users of ESES, the knowledge-frame format is maintained to enhance consistency among related documents.

The Environmental Sampling Expert System-Soil Metals (ESES-SM) incorporates both user factors and site factors to determine the design of a sampling plan. Figure I-1 depicts the interdependencies among the several factors involved. Analytes and characteristics of interest, intended use of the data, and resources available are summarized in the statement of the DQOs, which in turn determine the method requirements. The source, type, and extent of contamination, as well as field conditions, complement the input for preparation of a sampling plan. Based on information about these aspects, ESES-SM provides advice on a number of categories that form part of the sampling plan. These categories are: requirements for attainment of statistical confidence and representativeness (e.g., sample size, number, and location); QA/QC measures; sampling procedures, techniques, and equipment; sample handling and shipping; documentary procedures; and safety measures. Site and medium (soil) characteristics provide data and information as needed in the ESES-SM interdependency diagram.

ESES makes extensive use of hypertext techniques. Familiarity with hypertext techniques is needed to use the knowledge frames and information in a computer. Hypertext is a method to present information in a computer. Each portion of text presented on the computer screen may contain highlighted terms which can be selected for further explanation. The explanation will appear in a separate "window" on the screen and the user can return to the original text when finished with the window. Each explanation window may contain more hypertext terms, which can be selected at the user's command, forming a chain of concepts. This feature allows for various levels of on-screen information according to the user's level of background in the subject matter. Novice users can make extensive use of hypertext and find the system self-explanatory, while more experienced users will not be forced to read familiar information. The use of hypertext gives ESES and ESES-SM value as a training tool and also makes it appropriate for use by individuals with wide-ranging backgrounds and levels of expertise.

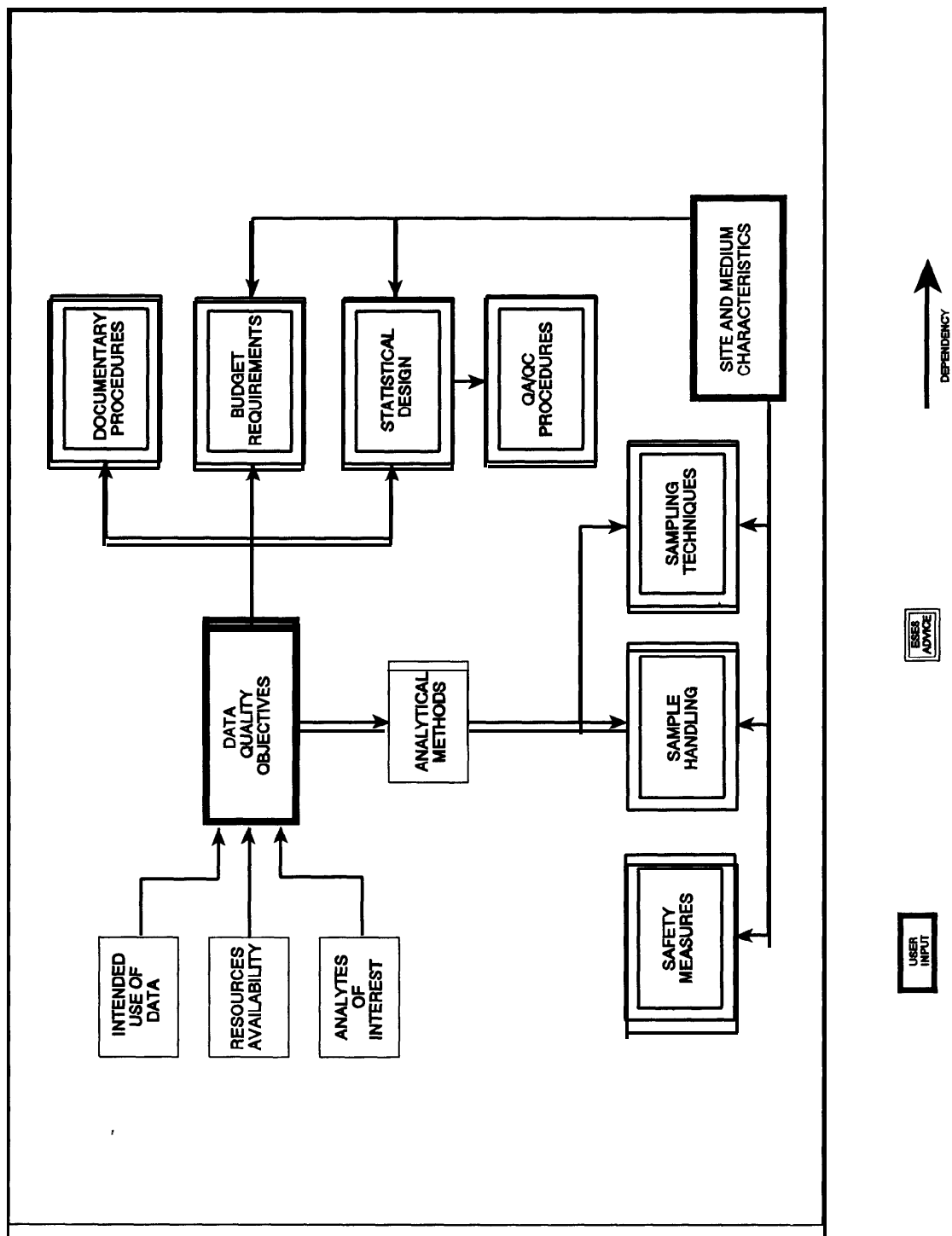


Figure 1.1. ESES-SM Module Interdependency diagram

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## **SECTION 2.0**

### **COLLECTION AND USE OF SITE AND SOIL CHARACTERIZATION DATA**

Site and soil characterization data, and knowledge and understanding of their variability are important components in developing the sampling plan for a particular hazardous waste site. These data impact many decision points in the integration of sampling plan elements (e.g., intended use of the data, analytes of interest, sampling and analytical methods, statistical design, remedial action). For hazardous waste sites, where a primary objective is to determine the nature and extent of contamination, site and soil characterization may be strongly oriented toward health and safety factors, not only for an initial entry team, but also for subsequent investigators. Data on environmental, ecological, climatic, physical, chemical and biological, and other factors, however, must be gathered not only to provide an overview of the site, but also to determine details as to its complexity and extent, and to adequately support decisions about data quality objectives (DQOs). Consequently, it is important to consider and synthesize data from all available sources in developing descriptions for a particular site and its soils. These sources include reference documents; site background reviews; field reconnaissance; actual sampling activities; and information from cooperating scientists in such fields as soil science, geology, hydrogeology, chemistry, agriculture, climatology and microclimatology, botany, zoology, ecology, photointerpretation, geographic information systems, statistics, quality assurance, and numerous engineering disciplines (e.g., agricultural, civil, and mechanical).

Regardless of the sources or methods of data collection, all elements of the site and soil characterization process must be designed and executed in a manner appropriate to the intended use of the data. Thus, both experienced and inexperienced field personnel should concentrate on identifying and asking the questions that will provide qualitative and quantitative data appropriate to solving the problems of interest at a particular hazardous waste site. The remaining discussions in this section are intended to aid in identifying the questions and issues of concern in performing the site background review, in describing and characterizing the site and the soils present, and in determining and supporting the intended use of the data.

#### **2.1 SITE BACKGROUND REVIEW**

Although direct, on-site observation provides the most detailed information about site and soil characteristics, basic data on site features can often be obtained from existing sources before field work begins. These data are often essential in planning reliable field reconnaissance and sampling efforts. The data may be general or specific, depending on the sources available for the particular geographic location.

During the site background investigation, the scientist should ask, at a minimum, eight basic questions concerning site and soil characteristics:

- **What is the area of the site?** Indicate the area of the site in hectares and describe the configuration (square meters, length and width).
- **What is the depth to ground water?** indicate the depth to ground water from the ground surface, and, to the extent known, identify seasonal fluctuation and the depth and thickness of multiple aquifers.
- **What is the level of ground-water use?** Identify both potable and nonpotable ground water use(s) by aquifer, if appropriate, and the point(s) of extraction relative to the site.
- **What is the potential or maximum rate of contamination?** Indicate the potential or maximum rate of various soil and ground water contaminations that impact the site. Include vertical flow rate through the unsaturated (vadose) zone to ground water, and any horizontal flow rate in the aquifer.
- **What soil “types” are present and what is their depth?** Identify, to the extent known, the site's soil strata, its characteristics, and its relative extent below ground surface. Characterization of the soil medium should begin with data available through soil surveys made by the SCS and through contact with soil survey personnel, local soil scientists, engineering personnel, and county extension personnel. This early investigation will save time and resources and will minimize duplication of effort in obtaining needed or desirable data on soil characteristics.
- **What sensitive receptors are in proximity to the site?** Identify population and environmental concerns relative to the site that could be impacted by contaminant migration through various media via air, surface water and ground water.
- **What and where are the locations of potential sources of site contamination?** Identify and locate potential sources of contamination that could impact the site under investigation as well as potential sources of contamination from the site to the surrounding environment.
- **What documentation is available? What resources can be accessed to obtain information about the site, its history, land use, land modifications, initiation and age of contamination, etc.?** Consult personnel, agencies and records.

Thoroughness in obtaining data on these topics will improve the efficiency and quality of subsequent planning and field work. Appendix A describes the components of a site/soils background review in more detail and lists major sources of data useful in the systematic assessment of hazardous waste sites.

## 2.2 SITE DESCRIPTION

After a designated site has been selected for investigation and the background review has been conducted, the area (landscape) around the site should be examined for its identifying characteristics,

and the resulting data and observations should be assessed in conjunction with the available documentation, such as soil boring logs from any previous drilling activities. These environmental observations on the climate, soil, ecology, physical and chemical attributes of the site should be as complete, objective, and clear as possible and should be recorded in a notebook or on a form devised for this purpose. The use of a standard form will assist in subsequent data entry and interpretation. A sample form is provided in Appendix C. A sample form for soil profile and related information also is provided in A Field Pocket Guide (Boulding, 1991).

The site reconnaissance is intended to confirm the results of the preliminary background review and to identify site characteristics that may indicate contaminant sources and migration paths, affected populations, and potential monitoring sites. Thus, it is insufficient to collect data on only the soils under consideration, information on site environment and its spatial and temporal variability are also needed. The investigator must also observe the surficial geology, topography, slope, erosion patterns (wind derived and water derived), streams and other water bodies, and surface microrelief. Other important observations include:

- **Evidence of animals and kinds of animals** (e.g., cattle, rodents, birds, wildlife) and their numbers and degree of activity. Sufficient time should be allowed for actual sightings, if needed. In addition to visual sighting of animals, evidences of habitation, tracks, paths of travel, feeding remains, fresh or old bones, fresh or decomposed dung, and distribution and numbers of burrows should be recorded, particularly with reference to source and extent of contamination. Consult the literature and area biologists regarding possible endangered species which may affect the approach to cleanup.
- **Plant species and distribution on- and off-site**, particularly with reference to effects of contamination on-site as determined by plant stressors. Note especially the types of vegetation, (e.g., trees, shrubs, grasses and other flowering plants), and note the lack of vegetation if little or none is present. Determine which kinds of vegetation are the most abundant or typical, and note their distribution (dense, scattered, irregular, or even) by species, and the amount of vegetative growth (prolific, moderate, or scant). Depending on the time of year, the climate, and the local weather (especially in a favorable moisture-temperature regime), and reproductive features (e.g., fruits and flowers) of plant species also may be noted. If possible, estimate the age and apparent health of the vegetation and plant stresses such as stunting, chlorosis, diseased tissues and organs and changes in kinds and distribution of vegetation. These vegetation features are important to determining the age and “health” of a disturbed site. Information also should be obtained regarding possible endangered plant species.
- **Meteorologic factors, climate and weather** are important site characteristics and also have an important role in soil formation and the amelioration and remediation of disturbed and contaminated soil sites. Long-term climatic data may be obtained from the U.S. Department of Commerce; weather information may be obtained from a local weather station. Meteorological and micrometeorological or microclimatic factors should be noted or measured because they may affect sampling procedures and safety considerations; the quality of the collected sample,

its handling, and subsequent storage and analysis; and instrumental measurements made on site. For example, to avoid contamination, samples should be protected from the wind. Collected samples should not be exposed to the sun or to high or varying temperatures, such as from varying cloud cover, or from high relative humidity. Precautions also should be taken in collecting, handling and storage of wet samples to avoid condensation and adverse microbial effects, e.g., anaerobic conditions, promoted by closed containers. External environmental factors, e.g., temperature, relative humidity, wind, solar radiation and evaporation, and barometric pressure, also may affect certain instrumental readings and analysis in the field. Field measurements needed to characterize the external site environment may include measurements for the nature and extent of cloud cover, relative humidity, barometric pressure, evaporation rate, temperature, meteoric precipitation (recent or present at time of sampling), and microclimatic wind profile (from surface to approximately 1 m above the surface), including wind direction and velocity. If instruments and time are available for these readings, it is advisable to take readings for extended periods (more than a few consecutive days), and for a given space (depth or profile) of the site environment selected for measurement and observation.

If possible, measurements should be made before, during, and after collection of samples. Diurnal environmental measurements, such as for temperature and humidity, are preferable to those made at only one point in time. If it is determined that other environmental factors could affect sampling, e.g., wind, then other microclimatic measurements may be made, especially if site disturbance varies from the undisturbed area. Additional measurements may include onset, amount, and duration of dew; net or total exchange of thermal radiation; occurrence, duration, and intensity of sunlight; and site elevation. Solar radiation data can usually be directly related to atmospheric stability; models to compute rates of chemical vaporization may use solar data quantitatively.

- ***Anthropomorphic features*** such as buildings, embankments, excavations, bridges, roads, impoundments, berms, dumps, landfills and debris, and any other artifacts or evidence of human activity, both past and present (e.g., visible household/industrial refuse and scrap; vehicle paths, tracks, and miscellaneous parts and fluids) should be noted.

It is better to make all additional observations or measurements of potential interest and to make too many notes, rather than too few. Record special or unusual features in the site environment that may influence the disturbed soil and the collection of samples (e.g., presence of hazardous materials or objects containing flammables, poisons, combustibles and radioactivity). It is also extremely important to record all observations while at the sampling site. Subsequent recall of pertinent information about the area, site, and in situ features of the soil is not reliable, and it may not be possible to repeat the observations due to constraints of time, circumstance, or logistics. Properly identified photographs and maps of area, site, soil, and other features, including sampling procedures, are important records for site characterization and for subsequent risk assessment, remedial actions, and possible testimony and litigation.



## 2.3 SOIL DESCRIPTION

Soil description for hazardous waste site investigation incorporates features of standard soil description and specialized data unique to the evaluation of metals contamination. Basic descriptive elements are discussed in Section 2.3.1. Application of these elements to different hazardous waste sites for investigative purposes is described in Section 2.3.2.

### 2.3.1 Basic Soil Description Components

A basic soil description considers the soil's physical location (Le., as a naturally occurring, three-dimensional piece of landscape), its derivation (parent materials) and development (soil forming factors), and its composition (i.e., minerals, organic matter [living and dead], water, and air).

Soils vary in their physical, mineralogical, chemical, and biotic properties, all of which, in consideration of their derivation and stage of development, constitute a descriptive kind of soil or soil "type" (map unit). Categorical or taxonomic units are used to classify soils. There are six major soil diagnostic features (epipedons) and fifteen horizon (diagnostic layer) descriptors, plus additional descriptors, such as for pans (hard layers). Disturbed or contaminated soils may not fit into the standard classification that soil scientists use. These soils, however, can still be characterized according to basic soil properties, in accordance with project DQOs. The knowledge frame on soil horizons provides information describing typical master horizons and layers, transitional soils and also disturbed, and buried soils which may be encountered at hazardous waste sites.

A "standard" soil description draws on many site, soil, and procedural characteristics (USDA Soil Conservation Service, 1987; also see A Field Pocket Guide, Boulding 1991). These characteristics include a taxonomic classification as to soil series; date of collection; site location (latitude, longitude, and elevation); slope; microrelief; geomorphic position; physiography; local landform and land use; depth to water table; flooding characteristics; pedon (soil body) classification; parent material; climatic and weather information, including weather station identification; vegetation cover and species; soil depth; diagnostic features; and collector's name and affiliation.

Specific soil information includes a classification of soils, horizon (strata) designations, thickness and depth; dry and moist color (Munsell notations); texture; structure; consistency (dry and moist); evidence and description of mottles (discolorations); surface features; evidence of roots; macro and mesobiota; pores; rock fragments; various kinds and shapes of concretions; and a description of organic matter. Field measurements may be determined for such characteristics as effervescence (carbonate), moisture content, hydraulic conductivity, infiltration and percolation rate, surface and subsurface temperature, pH, and Eh. Other samples should be collected which can be measured either in the field or solely by means of laboratory instruments, e.g., pH and Eh, specific ions, cation and anion exchange capacity, microbiota, electrical conductivity, water potentials, organic matter and its components.

Texture, structure and porosity are among the most important physical soil properties where solute transport is concerned and chemical migration is affected by mineralogy, especially clay minerals, Ph, Eh, and organic matter, although most metal species may be relatively immobile. Although soil texture can be roughly estimated in the field by "feel," mechanical analysis can be used to determine more than 40 textural classes; and 20 textural modifiers can be used to describe soils. Use of a soil texture triangle (Figure 2-1) provides a simple method of measurement for this parameter. A mechanical analysis can be performed to show that a soil that is 30 percent silt and 70 percent clay by texture, for example, is classified as "clay," whereas, a soil that is 60 percent sand and 30 percent clay is classified as a "sandy clay loam." Estimations of soil texture may require some experience. A laboratory analysis should be performed to determine the percentages of soil separates, sand, silt and clay, and resultant textural class.

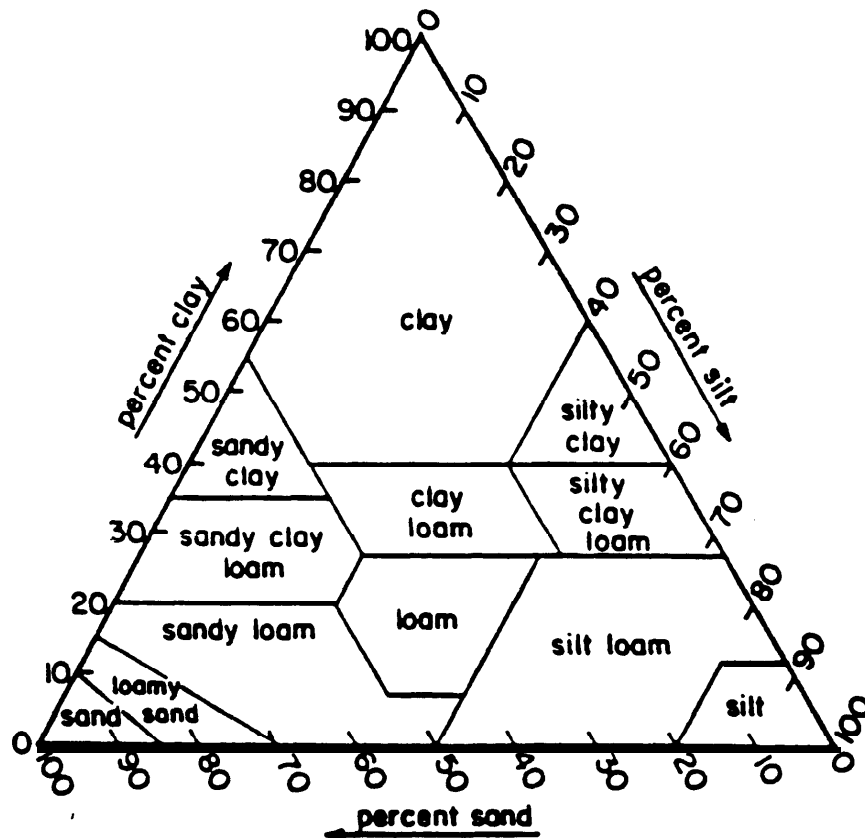


Figure 2-1. Soil Texture Triangle. Example: A soil with 20% clay, 40% silt, and 40% sand is a loam.

Various texture classes differing from those used in soil science in the United States are used in engineering operations and in other countries. The ASTM system and Unified Soil Classification System (USCS), for example, applied to design and construction of roads, airfields, dams, etc., group soils partly on the basis of particle-size distribution and partly on the basis of Atterberg plastic and liquid limits. For the USCS, four soil fractions are recognized: cobbles, gravel, sand and fines. Three major divisions are recognized with 15 soil groups. The major divisions are coarse-grained, fine-grained, and highly organic soils. The USCS can provide a rather good characterization of the particle-size distribution and physical behavior of soil materials, but due to its overall simplicity, it is suited primarily for an evaluation of fill materials and cannot be used to predict soil behavior in terms of chemical reactions (Dragun, 1988). Although the USDA system is directed toward identification of soils for agricultural and land use, it is sufficiently uniform for general prediction of chemical migration in soil and therefore also is of value for similar purposes in predicting migration of chemicals in contaminated soil. For site remediation and construction purposes, the ASTM or USCS may be preferred over that of USDA. A comparison is given below of the ASTM, USCS and USDA systems for classification of soil texture (Table 2-1).

TABLE 2-1.  
Comparison of ASTM, USCS and USDA Soil Textural Classification Systems

ASTM	Colloids	Clay	silt		Fine sand		Coarse sand		
USCS	Fines (silt or clay)				Fine sand		Medium sand		
USDA	Clay		Silt		Very fine sand	Fine sand	Medium sand	Course sand	Very coarse sand
	0.0001	0.001	0.01	0.1	1.0	2.0			

Particles size in millimeters

Many descriptors can be used for grade, shape, and size of soil structure. Depending upon the time, degree, and extent of possible manipulation at a given site, naturally occurring soil structure may be severely altered or destroyed. Soil structure descriptions should not be divorced from considerations of other soil properties, especially texture, horizon descriptions, porosity, and permeability.

Consistency is an indication of the degree of cohesion or adhesion of the soil mass, and can be determined as gradients of dry to moist, or as brittle, cemented, or fluid. A strongly cemented, or a sticky, plastic soil is not conducive to “standard” methods of soil sampling.

The content, activity (potential), movement and rate of flow of water is very important in the soil, not only for the growth of plants and microorganisms, but also in regard to migration, movement, and rate of movement of solutes, nutrients and contaminants. Measurements for water content, infiltration and penetration rate, various water potentials, and hydraulic conductivity, both saturated and unsaturated, are important in this regard. Water measurements, especially those for hydraulic conductivity, can be complex. A detailed knowledge frame is provided for hydraulic conductivity that includes some theory as well as practical understanding, usage and interpretation.

Soil inclusions can have an effect in determining the rate of water movement and solutes in the soil profile. There is less potential for water (and ions) to migrate through soil mottles of medium to coarse size (between 5 and 15 mm diameter). A change in the soil moisture regime may be indicated by the proportion of colored mottles. Light gray mottles may indicate a reducing soil environment, and a greater tendency for water activity than an oxidized environment of yellow-brown, brown, and red mottles. Naturally occurring mottles versus mottles formed from soil contamination should be noted, along with distinguishing surface features such as coats, stains, and films; their quantity; and their continuity. Soil color, minerals, aeration, and Ph-Eh are related features.

Boundaries of changes in the soil, such as in horizons, should be noted in terms of distinctness (e.g., abrupt, gradual, clear, or diffuse) and topography (e.g., smooth, wavy, irregular, or broken), especially in regard to the contamination source and its migration.

Soil microbiota (e.g., bacteria), along with mesobiota (e.g., earthworms), may not be determined for contamination sites, but they may provide, by their abundances, kinds and distribution, information about site contamination. They, along with the macrobiota, for example, rodents (macrofauna) or small and large animals (megafauna), may serve as “indicators” of contamination. Special care should be taken in the sampling and handling of soil for micro- and mesobiota to avoid sample bias, for example, microbial contamination, or alteration of populations in closed containers exposed to altering temperatures.

Soil organic matter is another important soil constituent and may be visibly apparent. It is usually reported in analyses performed by the SCS, along with soil Ph, effervescence, color, odor, and chemical constituents, both macronutrients, such as phosphorus, and micronutrients, such as iron. Organic litter also may occur on the surface of the soil in various stages of deposition and decomposition, and roots may be present in the surface or subsurface soils.

Changes in color, odor, and corrosivity may be important considerations in contaminated soils compared to uncontaminated soils, and may provide clues about the nature and extent of contamination. Most soil properties do not interfere with standard procedures in soil sampling (e.g., removal of surface litter prior to sampling or breaking up of compaction or crusts). In soils that

contain significant amounts of organic matter, however, metal-complexes (ligands) formed with organic matter are an important factor in sorption, fixation, and both the mobility and immobility of cations and anions, including metal species.

Other soil factors, such as kinds, numbers, sizes, and distributions of various concentrations (e.g., crystals, modules, nodes, masses, and concretions) should be noted in contaminated soils, especially if formed by processes subsequent to contamination. Kinds, shapes, number, and distribution of macropores (e.g., tubes, vesicles, or fragments) are relevant to infiltration, permeability and percolation; soil crusts, rock fragments, and stony or desert pavement likewise will affect these soil properties.

### 2.3.2 Description for Hazardous Waste Projects

A project description includes all response activity plans (US EPA, 1987). It is required in the quality assurance (QA) and sampling plans for remedial investigations and in the work plans for the Field Investigation Team (FIT) operations. The Site Manager (SM) is responsible for the successful completion of the work assignment, within budget and schedule. Pertinent information used to develop the project description is the responsibility of the SM. Information for the project description would include results of previous site investigations; any environmental permits associated with the site; tax records; results of inspections by other state, local, or federal agencies; newspaper accounts; records from community relations interviews; aerial photographs (such as those typically available from the Environmental Photographic Interpretation Center); and any other data that will assist the SM in developing the project description and statement of objectives. It is important, particularly on projects involving enforcement activities, that adequate records be kept to document the process by which project objectives were derived.

The project description should be site-specific and include at least the following items:

- Site description and history
- Schedule of activities
- Intended data usage
- Identification of samples matrices and parameters
- Sample design description and rationale

For the site description, all pertinent physical and land use information should be obtained. Maps, drawings, and photographs should be included, if available. These include the following:

- Size, including area within facility boundaries and the extent of contamination above defined thresholds (threshold limit value), if known.
- Specific location description, including directions and distances from nearby towns.
- Surrounding geography (e.g., town, city, county, or state boundaries and jurisdictions; power lines; railroads; roads; and topography)
- Physical and environmental description including the following:

- Geologic conditions
  - Soil "types" and depths
  - Surface water hydrology
  - Ground water hydrology
  - Flora
  - Fauna
  - Terrain
- Onsite conditions (e.g., the presence of pits, ponds, tanks, drums, standing water, buildings, and wells)
  - Climatological description for the region and for site-specific parameters, such as wind speed and direction, precipitation patterns, and freezing conditions
  - Demographics and surrounding land use (e.g., agricultural, industrial, or residential; populace at risk; and transportation patterns)

A review of EPA documents shows that the emphasis on soil characterization and the particular parameter to be determined vary considerably, depending on the DQOs for the particular hazardous waste project. For site characterization, attention usually focuses on the soil properties that are most useful in characterizing the soil-contamination system. For example, in site characterization, leaching potential and attenuation of contaminants are the major concerns; therefore, soil slope, surface drainage, the extent of highly contaminated soils, and the practicality of using particular field contaminant instrumentation may be the most important considerations in the soil description process (US EPA, 1986a). Additional major concerns could include the depth (thickness), texture, structure, porosity, roots, and nature of underlying geologic materials. As an adjunct to ground-water monitoring, on the other hand, the emphasis may be on soil properties that help establish the amount of contamination sorbed on aquifer solids that may contribute to ground-water contamination (US EPA, 1983). For this purpose, it is indicated that it is important to collect detailed information such as soil grain size (texture), cohesiveness, moisture content, color, and odor and to make numerous readings with field monitoring equipment for the designated soil parameters. In addition, it is indicated that physical factors such as temperature, oxygen, and light penetration should be measured to provide an interpretive basis for conditions that may radically alter the rate of chemical reaction and of associated microbial activity.

In contrast to the requirements for site characterization, the DQOs for remedial response activities may emphasize the collection of data for a different set of soil parameters. These data would include soil "type," Ph, cation exchange capacity, and physical measurements for hydraulic conductivity, hydraulic head, penetration rates, permeability, porosity, grain size, and bulk density. Additional observations might include a description of soil depth, hardness, stratification, discoloration, and surface depressions (US EPA, 1987a). These soil properties may be determined regardless of the nature of the contaminant. For metals, the vertical contaminant distribution is expected to be limited if the contamination occurred at the soil surface. Metals are relatively immobile and their downward migration is usually limited, dependent upon various soil properties, e.g., clay mineralogy, cation and ion exchange, organic matter content and distribution, moisture content and potential, infiltration and penetration, hydraulic conductivity and gradient.

When the project constitutes an emergency response, basic data are needed not only regarding the soil per se, but also erosion, type of surface runoff, and slope characteristics. Of particular importance are soil texture, structure, consistency, infiltration and permeability, cations and anions, and exchange capacity for clay minerals and organic matter. Mason (1983) provides useful guidance in these areas.

## 2.4 INTENDED USE OF DATA

Intended use of the data may focus on site characterization, health and safety, risk assessment, evaluation of alternatives, engineering design of alternatives, monitoring during remedial action, identification of potentially responsible parties (PRP), or possible use in litigation. Each type of use may necessitate sampling of soil for the required remedial investigation and remedial response activities.

The quality, quantity, and level of detail for collected data and information will vary and are largely based on their intended use. Each site has a unique history, and the amount and quality of data available will vary. These factors must be considered in establishing and working toward the DQOs for the project. Data quality, quantity, and intended use will impact site-specific decisions, the needs of data users, and the requirements for further sampling and analysis.

DQOs should be based on data-use categories. Specific site investigations may require data for one or more purposes, but as a rule methods for collecting and analyzing data should be designed to satisfy project DQOs at a level appropriate for remedial response activities.

Data use categories for remedial activities are discussed in US EPA 1987b and are summarized as follows:

- **Site Characterization** - Data generated through the sampling and analysis of waste sources and environmental media are used to determine the nature and extent of contamination at a site.
- **Health and Safety** - Data are used to establish the level of protection needed for site investigators or workers and to establish precautions needed to protect populations in the vicinity of the site.
- **Risk Assessment** - Data are used to evaluate the threat posed by a site to public health and the environment. Risk assessment data are generated through the sampling and analysis of environmental and biological media, particularly where the potential for human exposure is high.
- **Evaluation of Alternatives** - Data are used to evaluate available remedial technologies and to develop cost estimates. Evaluations may involve performing bench-scale or pilot scale studies to determine the effectiveness of a particular process or material.

- **Engineering Design of Alternatives** - Data collected during the remedial investigation/feasibility study (RI/FS) can be used to develop a preliminary engineering design data base on the performance of remedial technologies. Data applicable to the remedial design (RD) process include waste characterization and preliminary volume estimates. These estimates usually need to be refined during the Remedial Design/Remedial Action (RD/RA).
- **Monitoring During Remedial Action** - During the remedial action, samples can be taken to assess the effectiveness of the action. Based on the analysis of these samples, corrective measures may be taken.
- **PRP Determination** - Data may be used to help establish liability at multiple-party sites. For known PRPs, data are used to link their wastes to those found on the site and to pollutants released to the environment. For unknown PRPs, data are used in comparing the site wastes to pollutant profiles of known waste streams. Data are also used for injunctive actions and cost recovery.
- **Litigation** - For this purpose, policies, procedures, and documentation should meet EPA National Enforcement Investigations Center (NEIC) requirements (US EPA, 1978). Activities and procedures of interest include project review, background review, project plans, project activities, and report and follow-up on pollution problems related to all media. The US EPA recommends Contractor Laboratory Program (CLP) procedures for litigation purposes.

After the data-use categories pertinent to a project have been determined, their order of priority should be established according to the most stringent demand for use of the data. Thus, the highest priority is the data use that requires the highest level of confidence and the lowest level of data uncertainty. The limits of uncertainty will drive the selection of project analytical and sampling approaches, including those for soils.

Soil measurements needed to support CERCLA decision-making processes have been outlined by Breckenridge et al. (1991). In addition to those included in the knowledge frames of this guide, these are depth to ground water, liner soil/water partition coefficient, the organic carbon partition coefficient, and water erosion Universal Soil Loss Equation. Boulding (1991), in *A Field Pocket Guide* provides additional tests and methods, including engineering properties and parameters: Atterberg limits (consistency), shear strength, shrink-swell, and corrosivity. Corrosivity (corrosion potential) and consistency are included as knowledge frames in this guide. Atterberg limits are included in the "consistency" knowledge frames.

Once priorities for intended data use have been established, the data types that need to be developed are identified. Subsequently, data quality needs are defined, and soil sampling and analysis options are evaluated. Data types can then be categorized to form a decision matrix to meet the specifications of the data type needed for each intended data use.



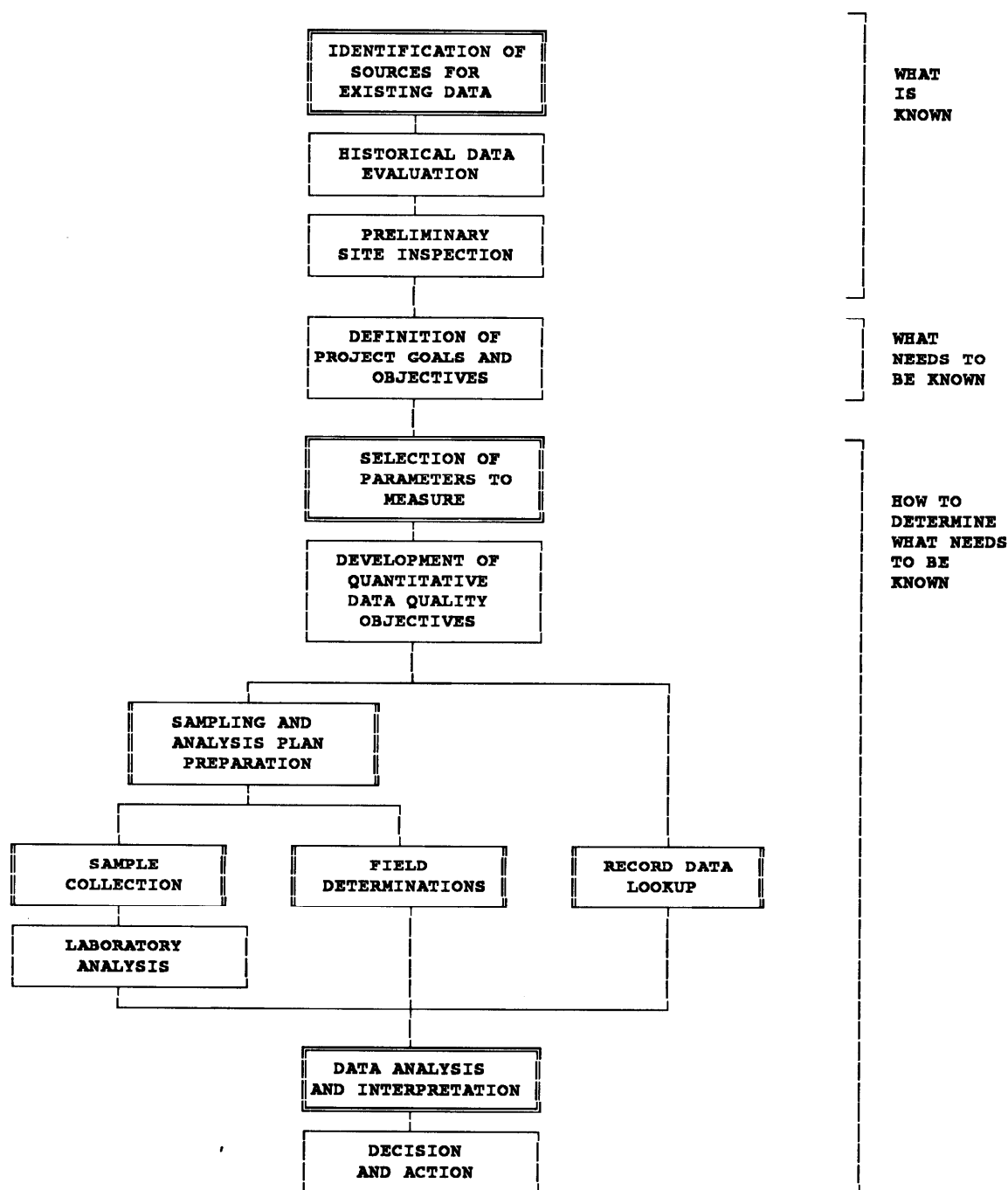
The integration of site and soils data collection methods, DQO selection, and data uses involves many complex decisions. Mason (1983) provides useful flow charts and decision trees for site and soil characterization. US EPA (1987a and 1987b) offers guidance on the development and application of DQOs. Sections 3 and 4 of this guide are intended to aid the decision process by providing a uniform basis for identifying site and soil characteristics in the field, whether measured in the field or when a soil sample is subsequently taken to the laboratory for subsequent analysis.

This knowledge book may be used in conjunction with the Field Pocket Guide for measurements and tests to be performed in field or on samples returned to the laboratory for analysis. Figure 2-2 illustrates the relationship of various aspects of ESES, the knowledge book and Field Pocket Guide and the appropriate, sequential use of the two guides. It should, however, be considered that the knowledge book also is available in the computer.

Site and soil characteristics and parameters are included in both the knowledge book and Field Pocket Guide. Correlation of these parameters is given in Table 2-2. The list of parameters is followed by the method of determination in the field and/or laboratory, and/or a "Lookup" in relevant references. A discussion of the specific parameter also is indicated for the knowledge book in the Field Pocket Guide.

The scope of the Field Pocket Guide is much broader than that of the knowledge book and therefore includes additional or supplementary tests which may be performed, e.g., soil engineering tests and those related to organic contaminants and wastes. In Appendix D of this document, principal site characteristics and soil parameters are included along with a brief, specific mention of field and/or laboratory methods, calculations or data/information to be looked up and appropriate references.

The US EPA SW 846 manual (US EPA, 1986b) should be used whenever possible for test procedures to evaluate those properties of a solid waste which determine whether or not the waste is defined as a hazardous waste according to Section 3002 of RCRA (PL 94-580). The methods delineated in this manual are approved for obtaining data to satisfy the requirement of 40 CFR Part 261, "Identification and Listing of Hazardous Waste." This manual encompasses methods for collecting representative samples of solid wastes, and for determining the reactivity, corrosivity, ignitability, and composition of the waste and the mobility of toxic species present in the waste. Several methods for soil tests are included, i.e., cation exchange capacity, pH, and hydraulic conductivity (saturated), and are referenced in Appendix D.



 Guide to Site and Soil Description use

 Field Pocket Guide use

Figure 2.2. Applicability of Guide to Site and Soil Description and Field Pocket Guide to Site Characterization Phases.

TABLE 2-2.  
Site and Soil Characterization Parameters and Their Determination.  
Adapted from Russell Boulding (Eastern Research Group)

Parameter	Site and Soil Guide	Determination Method		
		Field	Lab	Lookup
1. Water Budget Parameters				
a. Precipitation		•		•
b. Infiltration	o	•		
c. Evaporation		•		•
d. Evapo-transpiration		•	•	
e. Surface Runoff	o	•		•
2. Other Climate Parameters				
a. Air temperature	o	•		•
b. Wind speed/direction	o	•		•
c. Humidity		•		•
d. Insolation		•		•
3. Geomorphology				
a. Slope gradient/length	o	•		•
b. Slope form/landscape position		•		•
4. Erodibility	o			
a. Water Erosion	o	•		•
b. Wind Erosion		•		•
5. Surface Hydrology				
a. Surface streams		•		•
b. Flood frequency/duration		•		•
c. Water Bodies		•		•
6. Site Biota				
a. Vegetation	o	•		•

- - Can be determined where indicated
- o - Discussed in "Guide to Site and Soil Description . . ."
- s - Take sample in field for laboratory analysis

Parameter	Site and Soil Guide	Determination Method		
		Field	Lab	Lookup
7. Horizons	○	●		●
8. Texture	○	●	●	●
9. Color	○	●		●
10. Porosity	○	●	●	●
11. Zones of Increased Porosity/Permeability				
a. Soil Structure	○	●		●
b. Roots	○	●		
c. Lateral features	○	●		●
d. Sedimentary features		●		
12. Zones of Reduced Porosity/Permeability				
a. Genetic horizons		●		
b. Consistency	○	●	●	
c. Bulk density	○	●		
d. Root Restricting layers		●		
13. Soil Engineering				
a. ASTM (Unified) texture		●	●	●
b. Atterberg limits		●	●	
c. Shear strength		●	●	
d. Compressibility				●
e. Bearing capacity			●	●
f. Compaction	○	●	●	●
g. Erosion resistance		●		●
h. Shrink-well			●	●
i. Clay dispersivity		●	●	
j. Frost heave				●
k. Corrosivity	○	●	●	●

Parameter	Site and Soil Guide	Determination Method		
		Field	Lab	Lookup
14. Soil Water State				
a. Moisture content	○	●	●	●
b. Water potential		●	●	●
c. Water retention		●	●	●
d. Available water capacity		●	●	●
e. Moisture regime	○	●		●
15. Internal Free Water (Saturated Zone)				
a. Depth		●		●
b. Thickness		●		●
c. Duration		●		●
16. Permeability/Hydraulic Conductivity	○			
a. Saturated	○	●	●	●
b. Unsaturated	○	●	●	●
17. Contaminant Transport in Soil Water				
a. Velocity		●		●
b. Water/solute flux		●	●	●
c. Dispersivity		●	●	●
18. Volatilization (see, also 20a to 20e)				
a. Air permeability		●	●	●
b. Gas diffusivity		●	●	
c. Gas flux		●		●
d. Air temperature (see 2.a)	○	●		●
e. Wind speed (see 2.b)	○	●		●
19. Ground Temperature				
a. Soil temperature	○	●		
b. Soil temperature regime	○	●		●

Parameter	Site and Soil Guide	Determination Method		
		Field	Lab	Lookup
20. Soil Chemistry				
a. Organic carbon/matter	○	●	●	
b. Odor	○	●		
c. Cation exchange capacity	○	s	●	●
d. Soil Ph	○	●	●	●
e. Soil oxygen		●	●	●
f. Redox potential (Eh)	○	●	●	●
g. Redox couple ratios (waste/soil systems)		s	●	
h. Clay Mineralogy	○	●	●	●
i. Other Mineralogy		●	●	●
j. Salinity (EC)	○	●	●	●
k. Sodicity (SAR)		●	●	●
l. Major cations		s	●	●
m. Major anions		s	●	
n. Fertility potential	○	s	●	●
21. Soil Biota				
a. Enumeration	○	s	●	
b. Metabolism		s	●	
c. Nutrients		s	●	
C:N:P ratio				
other nutrients				
d. Activity/kinetics		s	●	
e. Macrofauna and Mesofauna	○	●	●	●
f. Microbiota	○	s	●	●
22. Soil Pollution Situation				
a. Type	○	s	●	●
b. Concentration	○	s	●	
c. Odor	○	●		
d. Depth	○	●		●
e. Volume		●		●
f. Date(s) of contamination				●

Parameter	Site and Soil Guide	Determination Method		
		Field	Lab	Lookup
23. Contaminant Hazardous Properties a. Toxicity b. Reactivity c. Corrosivity d. Ignitibility	o	• • • •	• • • •	• • • •
24. Contaminant General Chemical Properties a. Chemical class b. Molecular weight/structure c. Melting point/boiling point d. Specific gravity/density e. Water solubility/miscibility f. Speciation g. Dielectric constant			• •	• • • • • • •
25. Contaminant Chemical Reactivity a. Acid/base b. Oxidation/reduction c. Complexation d. Hydrolysis e. Catalysis f. Precipitation/dissolution g. Polymerization			• • • • • • •	• • • • • • •
26. Contaminant Volatilization Parameters a. Henry's Constant (Kh) b. Vapor pressure c. Vaporization temperature/ solubility (see 24. c and e) d. Koc sorption (gaseous phase)		s	•	• • •
27. Soil Contaminant Sorption/Retention a. Koc b. Linear Kd c. Nonlinear sorption constants d. Octanol-water (Kow) e. Residual saturation (Ko)		s • s  s	• • • • •	• • • •
28. Soil Contaminant Degradation a. Half-life/rate constant b. Biodegradability c. Degradation daughter products		 s s	• • •	• • •

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## SECTION 3.0

### SITE KNOWLEDGE FRAMES

Sections 3 and 4 present site and soil knowledge frames that can be used in the field to identify and describe soils. The knowledge frames are presented in ESES format in order to maintain continuity between ESES documentation and derivatives such as this guide.

Each frame consists of the following information.

- An OBJECT/ATTRIBUTE line that indicates the particular characteristic to be identified or described (e.g., clay minerals, slope, Ph).
- A DEFINITION of the overall characteristic.
- A list of VALUES for the characteristic, that is, the conditions that may be assigned (e.g., high, moderate, low; prominent, distinct, faint).
- CATEGORY and PROPERTIES assignments (necessary to the operation of ESES but not of concern in the field).
- REFERENCES, keyed to a references cited section at the end of the document.

The following site knowledge frames are presented in Section 3:

Nature of Heavy Metal Soil Pollutants  
Climate and Weather  
Slope  
Surface Erosion and Erodibility  
Surface Pollution Situations  
Surface Runoff  
Vegetation  
Wind Speed and Direction

Soil knowledge frames are presented in Section 4. The frames on the nature of heavy metal soil pollutants and on meso- and macrofauna can be considered either site or soil characterization. Metals are included with site characterization because they are generally a surface pollutant. Meso- and macrofauna are included with the soil knowledge frames although they are both on the surface and subsurface and have interaction with the pedon. The extensive site knowledge frame for the nature of heavy metal soil pollutants is the first knowledge frame to follow.



OBJECT/ATTRIBUTE: SITE/NATURE OF HEAVY METAL SOIL POLLUTANTS

DEFINITION: Contamination of the soil with metals that have densities > 5 g/cc and that do not decompose, but tend to remain in the soil indefinitely.

VALUES: RELATIVELY MOBILE AND TOXIC  
RELATIVELY NONMOBILE AND NONTOXIC

CATEGORY: SITE BACKGROUND

PROPERTIES: INPUT FACT

REFERENCES: Bear, 1957	Kabata-Pendias, 1987
Bergkvist, 1987	Kabata-Pendias and Pendias, 1984
Bonnyai, et al., 1988	Kabata-Pendias and Piotrowska, 1983
Breton, et al, 1986	Kobus and Kabata-Pendias, 1977
Camerlynck and Likens, 1982	Lodenius, 1987
Colwell, et al., 1987	Mason, 1983b, pp. A1 -10
Corbitt, 1989	Mattigold, Sposito, and Page, 1981
Corbitt, et al, 1989	Mayer and Schultz, 1987
Czupyma, et al., 1989	McCall and Pohlman, 1987
DeHaan and Bolt, 1979	Palmer, et al., 1988
Franson, 1985	Shaw, 1989
Glysson, et al., 1989	Sims, et al. 1986
Godbold and Huettermann, 1987	Stupar et al. 1991
Greszta, 1988	US EPA, 1986b
Jacobs Engineering Group, Inc., 1989	Vinogradov, 1959

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VALUE: Relatively mobile and toxic

DEFINITION: Residence time of the toxic heavy metals (density > 5 g/cc) in either the solid or liquid phase is relatively short, thereby enhancing active toxicity.

CONDITIONS: The behavior and fate of metals added to soils are governed by the complex and dynamic soil system involving physical (and mineralogical), physical-chemical, chemical and biological reactions. Unlike many hazardous organic constituents, metals in the soil system cannot be readily degraded or detoxified. They tend to represent a long-term threat in the soil system unless they can be permanently immobilized or removed.

Concentration in the soil solution, rather than total quantity in the soil, is the primary concern. Soil factors favorable to easy removal from soil particles and leaching promote accumulation in the soil solution and subsequent accumulations in plants and natural waters where they may be harmful.

Soils can accumulate specific metal ions from solubilized wastes or waste solution as well as release them if subsequent additions of wastes alter soil factors, e.g., acid pH and solubilization of organic matter. Reduced forms, even though present in low concentrations, are more likely toxic, e.g., copper as cuprous rather than cupric.

Heavy metals are, by definition, those elements having a density  $> 5$  g/cc in their elemental form. They comprise 38 elements, but in usual terminology, they refer to twelve metals most commonly used and discharged as wastes by industry: cadmium, chromium, cobalt, copper, iron, mercury, manganese, molybdenum, nickel, lead, tin, and zinc. The metalloids, boron and selenium are often included. EPA's list of inorganic priority pollutants includes antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium, zinc and cyanide. Those that may present the greatest potential hazards to animals, humans, or plants are considered to be cadmium, copper, lead, mercury, nickel, and zinc. A knowledge of metal/metalloid and cyanide sources is very useful in identifying and determining possible hazardous site and soil (and also subsurface and groundwater) contaminants, their behavior and migration.

The main sources of heavy metal contaminants are (1) industrial and urban aerosols, such as those created by fuel combustion, metal ore refining, and other industrial processes; (2) liquid and solid wastes from animals and humans; (3) mining wastes; and (4) industrial and agricultural chemicals. Industrial solid wastes also should be included. In industries that use metals or are involved in processes that use metals, metalloids or cyanides, sources of wastes result from off-specification products, spills, processing wastes, and hazardous by-products. There are more than 125,000 generators of metal/cyanide RCRA wastes. They are generated largely by metal fabrication facilities, which perform forming, plating and coating operations. These same facilities also tend to generate concentrated solutions, such as spent baths, which can be affected by the land disposal ban. Vehicle maintenance facilities also generate metal wastes, e.g., lead batteries in large numbers and volumes. Other large generators of waste include the printing and photographic industry (which primarily generate silver wastes), and metal manufacturing facilities, which generate metal plating and cyanide streams.

Regulatory Impact Analysis (RIA) data show that in decreasing volume of combined waste, the following can be shown: chromium, cyanide, lead, cadmium and nickel, with lesser amounts of mercury and arsenic, followed by smaller quantities of selenium and thallium. This ranking appears to be in general agreement with industrial use

patterns, publicly owned treatment works discharge, and other hazardous materials surveys.

Waste sources of metals, metalloids and cyanides result primarily from processes involving metal surface treatment (electroplating, immersion plating, chemical etching, chemical milling and bright dip); printed circuit board manufacture; petroleum refining (including waste water treatment sludges); inorganic pigment manufacture; wood preservation (one of the largest sources of arsenic containing wastes); and miscellaneous industries such as photography, printing, rubber and chemical manufacturing, pigment production, steam-electric industry, production of explosives, catalyst bases, metal forming and production industries, and nonferrous metals industries. In addition to metal wastes, associated wastes, frequently discharged into streams and in soils or in containers, can contain acids such as hydrochloric, sulfuric, hydrofluoric, and boric acid. Primary alkalies can include sodium hydroxide and sodium carbonate. Metals can also be frequently discharged into streams that contain complexing agents with cyanides, amines, ammonia (and its derivatives), EDTA, NTA, citrate, tartrate, oxalate and gluconate. Smaller quantities of organics can include oils and grease, solvents and metal finishing baths, which can also contain quantities of metals.

In agriculture, a small percentage of agricultural pesticides may contain arsenic, copper, mercury, manganese, lead, or zinc concentrations of heavy metals. The metals accumulate in soils by the repeated application of sludge over a long period of time. They can result, for example, in considerable movement of zinc, and to a lesser extent, cadmium and nickel to depths below 15 cm following surface applications.

Atmospheric metal deposition to ecosystems occurs primarily as precipitation (meteoric) and dry deposition; in some ecosystems, particularly at high elevations, cloudwater may be a significant input of industrial emissions. The relative contribution of precipitation, cloudwater, and dry deposition to a forest and the effect of the forest canopy on throughfall of metals and their chemistry vary depending on site factors including elevation, topography, and vegetation. The relative contribution of wet versus dry deposition may also influence the relative solubilities of metals and, in general, metals are less soluble in dry than in wet deposition.

Additions of metals to soils and subsequent uptake from soils to plants is the major mode of entry into the tissues of plants, animals and humans. The fate of heavy metals, including their mobility, absorptivity, and reactions in the soil, and their subsequent uptake and distribution in edible plant parts is of critical importance in human health. Soil contaminated with heavy metals can produce apparently normal crops that may be unsafe for human or animal consumption. See knowledge frames on site vegetation for further information on vegetation-metal interactions.

Permissible or “safe” levels of heavy metals, especially if used on farmland, are considered on the basis of several interrelated factors. Critical levels of metallic contaminants that exhibit toxic effects on biota and the environment can often be related to the cation exchange capacity (CEC), with a higher CEC more closely related to toxic effects. See the section on cation exchange and also the knowledge frame on soil CEC.

Usually, depending on the geochemistry of the specific metal, the resistance to toxic effects of a nonacid, fine-textured clayey soil can be several times the resistance of a coarse-textured or sandy, acidic soil. Loamy soils with approximately neutral pH may accumulate higher levels of heavy metals with much less risk to the environment, plants and animals. Generally, a chemical imbalance, such as from the addition of metal contaminants may result in alteration of soil properties, e.g., increase or decrease in Ph, Eh, cation exchange and biological activity, and decrease in mineral and organic adsorption complexes. See the knowledge frame on soil organic matter for further information on soil organic matter and humus, and organo-metal interactions.

Permissible or tolerable levels of heavy metals at a particular site should consider the interrelationships of the following conditions and factors.

1. Initial trace element content of soil as determined in noncontaminated off-site soil.
2. Total amount added of one particular element and of all heavy metals.
3. Cumulative total load of heavy metals in the soil system.
4. Heavy metal dose limitation.
5. Equivalency of trace element toxicity to plants as compared to off-site plants.
6. Threshold values of trace element concentrations in soils.
7. Relative ratios between interacting heavy metal elements,
8. Soil characteristics, e.g., CEC, pH, free carbonates, organic matter, clay content, structure, and moisture relationships.
9. Input-output balance, mobility and immobility.
10. Plant sensitivity to heavy metals in soils and solution.

The solubility and therefore mobility of metal elements in soils depends considerably on complexing or chelation with organic matter. In the soil aqueous phase, organic compounds and water are the most abundant ligands, therefore hydrolysis and organic complexing are the most common reactions. These reactions are pH sensitive and can be correlated with the size and charge of the cations. Higher ionic potentials usually indicate a higher degree of hydration in the soil solution, and consequently, easier precipitation. Depending on the pH for the precipitation of metal hydrous oxides, the order of cation mobility in the soil solution under an oxidized system may decrease as follows:

Divalent magnesium = divalent calcium > divalent mercury > divalent manganese > divalent cadmium > divalent nickel = divalent cobalt = divalent lead > divalent beryllium > divalent zinc = divalent copper > trivalent chromium > trivalent bismuth > trivalent iron > trivalent tin.

The transport of dissolved metal elements occurs in surface runoff, the movement of the soil solution and during leaching. Generally, in soils formed under a cool and humid climate, the leaching of metal elements downward through the profiles is greater than their accumulation, unless there is a high input of these elements into the soils. In warm, dry climates, and also to some extent in humid hot climates, upward translocation of metal elements in the soil profiles is the most common movement. However, specific soil properties, mainly its cation exchange capacity, control the rates of element migration in the soil profiles.

Depletion of metals and nutrients in soils is due mainly to their mobility downward with percolating waters through the profiles of freely drained acid soils and also their uptake by plants. On the positive side of the balance is the input of these elements and ions with atmospheric precipitation and their accumulation in particular soil horizons. An accumulation of metals usually occurs on the soil surface or in surface horizons (A and O) and downward movement in the soil profile does not occur to any great extent unless the buffer capacity of the soil is overcome; soils have a finite buffer capacity for heavy metals. In acid soils, several elements, such as zinc, manganese, copper, iron, cobalt, and boron, are easily leached. These elements, however, are likely to form quite stable compounds if the pH of the soil rises above 7. Other elements, such as molybdenum and selenium, are mobilized in alkaline soils, while in acid soils they become almost insoluble.

Several detailed studies based on lysimetric experiments, and other research often using isotopic tracers, have yielded much information on element transport. However, each soil profile with developed horizons has its own characteristic metal element movement or nutrient.

Adsorption is a common process for removal and immobilization of chemical elements and ions, including contaminant metals, from the soil solution onto soil particles. This process is largely governed by the surface charges of soil particles and is caused primarily by ionic substitutions, mainly by soil colloids, especially colloidal organic matter - the humus fraction. At a low pH a positively charged surface prevails, while at a high pH a negatively charged surface develops. The colloids of the majority of soils, therefore, carry negative charges and can be electroneutralized by cations present in the surrounding solutions. In the presence of an excess of cations, the process of exchanging the cations for others maintains the electroneutrality of the system. Thus, the cations adsorbed by the soil solid phase can be replaced by other cations, most often by hydrogen ions. An increase in stability of adsorbed metals may

result from dehydration and recrystallization processes that occur on the surface of the colloids, especially in alkaline soils.

The ability of the soil solid phase to exchange cations (cation exchange capacity - CEC), is one of the most important soil properties governing the cycling of metal elements and ions in the soil. The excess amount of adsorbed cations compared to the amount in solution is interpreted as the buffering capacity of soils, while adsorption capacity defines the amount of ions needed to occupy all adsorption sites per unit of mass.

The CEC of different soils varies widely both in quantity and quality and can range from 1 to <100 meq/100 g of soil. Surface properties of soil particulates are the most important factor in defining the capacity for adsorption of the microcations. Although total adsorption processes cannot be related simply to CEC phenomena, the adsorbed amounts of cations are in accordance with the CEC. Usually the soil solid phase with a large surface area, e.g., clays, also shows a high CEC value and high adsorption and buffer capacities.

The degree of attraction or affinity of cations for adsorption, e.g., for ionic exchange sites, is closely related to ionic potential (charge/radius). In some systems the metal ions (zinc, cadmium and manganese) occupy nearly the same percentages of the CEC as the various soil minerals. Some cations, however, may have a higher replacing power than others and can be selectively fixed by the sorbing sites. See knowledge frame on cation exchange capacity.

In general, and depending on soil properties and their behavior in a number of soils, but not necessarily a specific soil or "type," mobile and toxic heavy metals and metalloids may be categorized as antimony, beryllium, barium, mercury, nickel, selenium, tin, thallium and zinc. Cyanide is also included in this section. See individual descriptions for mobility and toxicity factors. Also included here, but generally less toxic except under specific conditions, are aluminum, boron, iron and manganese. In general, cadmium, nickel and zinc are relatively mobile and are taken up by plants (see Tables 3-1 and 3-2). See knowledge frame on site vegetation and soil organic matter for additional information.

Toxicity of a hazardous waste site, as defined by EPA, refers to a toxicity determined by the Extraction Procedure (EP) Toxicity Test. The EP toxicity test is a laboratory test designed to simulate leaching of waste in a sanitary landfills. A representative sample of waste is extracted and analyzed. If threshold levels of eight metals and four pesticides and two herbicides are exceeded, and the extract contains one or more of the contaminants in amounts equal to, or exceeding the specified levels, the waste is considered toxic and is classified as hazardous according to the EP Toxicity Test (see Table 3-3).

The frequency of occurrence of metals and metalloids determined during preliminary site investigations and reported by Field Investigations Teams (FITs) for 436 sites is as follows:

lead > arsenic > cadmium > chromium > copper > mercury > nickel >  
beryllium > manganese > silver > selenium

Less than five sites were found to have antimony, barium, boron, cobalt, molybdenum, thallium, tungsten and vanadium.

Antimony content in rocks is very small, usually < 5 ppm. It is enriched in sulfides, and during oxidation of sulfides enters into sediments and soils. Argillaceous sediments may contain as much as 2 ppm. As a metal, it is grey, lustrous and crystalline, appearing similar to metallic arsenic. The geochemistry and chemical behavior of antimony are closely related to that of arsenic, and secondarily to bismuth and phosphorus. Similar to arsenic, it is amphoteric, acting as both metal and nonmetal. Antimony usually occurs in the trivalent form, but occasionally in the pentavalent form. It is considered to be relatively highly mobile and can be associated with iron hydroxides. Antimony compounds are much less toxic than arsenic compounds, but more so than bismuth compounds. In surface soils it ranges from 0.05 to 4 ppm. In mature leaf tissues of various plants, it ranges from 7 to 50 ppm. Toxic or excessive limits are 150 ppm or more. The average for antimony in soils is approximately 1 ppm. Antimony, as for arsenic, may be found associated with nonferrous ore deposits. It can be found around smelter operations and is considered to be a pollutant subject to long-range transport. Antimony is a component of type metal; and both antimony and arsenic are used to harden lead alloys destined for lead shot, bullets, bearings, battery grids and cable sheathings. Whereas burning of arsenic forms arsenides, antimony yields stibnides.

Beryllium is very toxic, indeed perhaps the most toxic, metal in the environment. There is more beryllium in soils developed from clays than from limestone or igneous rocks. It resembles aluminum in a number of properties. Activity in soil may resemble that of calcium and magnesium. It is known to be strongly adsorbed in soil and occurs most often in the divalent form. Its concentration in soils ranges from 0.1 to 40 ppm, with a mean of 10 ppm, but with concentrations higher near beryllium deposits. Although it appears to be rather immobile in soils, its salts, such as beryllium chloride and beryllium sulfate, can be adsorbed by plants, resulting in toxicity. In various plants under natural conditions, its concentration ranges from 0.001 to 0.4 ppm. Beryllium is added to the soil in wastes such as rocket fuels; certain light, hard and corrosion-resistant alloys; and in ceramics. Concentrations are higher in soils near smelters and coal-fired power plants.

Boron, a metalloid, is easily solubilized during weathering, forming several anions. It is likely to be retained by clays, particularly illites, but also by sesquioxides and organic matter. Its retention is greater on sesquioxides than on clay minerals. The most

common form of boron in soil solution is boric acid, and in part, boric hydroxide. Boron solubility in soils may be governed by oxides of iron and aluminum. Organic matter has a strong influence on boron mobility and availability, particularly in acid soils. Boron reactions are highly pH dependent, especially when  $\text{pH} > 7.0$ . In arid zone soils, boron is likely to be coprecipitated with magnesium and calcium hydroxides as coatings or stains on soil particles. In soils, boron is considered to be the most mobile element among the micronutrients, and therefore follows the movement of water in the soil profile. In cool humid regions it is readily leached, but in warmer areas it may concentrate in the surface horizons. It also may concentrate in soil horizons enriched with illite. Some soils of arid and semiarid regions may contain toxic levels of boron. Some sewage sludges and fly ash also may add significant boron contamination to the soil. Soluble forms of boron are easily taken up by plants. The soil pH is the most important factor affecting availability to plants. In alkaline soils, the availability of boron increases with an increase in soil pH, which increases its potential for toxicity, especially with available water, either rainfall or irrigation. The normal content of boron in various mature plant leaf tissues is 10 to 200 ppm. Depending upon the plant species or crop, boron toxicity varies from approximately 250 to 5,000 ppm, usually  $> 500$  ppm. The common range in soils is 2 to 100 ppm. Other than sewage sludges, boron contamination in soils can result from wastes such as aluminum alloys, steel and electrical wires, fiber-reinforced materials and aircraft parts.

Cadmium in natural soils is largely dependent on the chemical concentration of the parent rock. Cadmium is concentrated in argillaceous and shale deposits. It is strongly associated with zinc in its geochemistry. It exhibits a higher mobility than zinc in acid environments. During weathering, it is readily solubilized to the divalent form but also forms complex ions and organic chelates. The most important factors concerning its mobility are pH and Eh. Above pH 7.5 cadmium is not readily mobile in soils. In acid soils, the organic matter content and sesquioxides may largely control mobility. Cadmium is most mobile in acid soils at pH 4.5 to 5.5. It is rather immobile in alkaline soils.

Cadmium is one of the most hazardous of the heavy metal soil pollutants to human health and is easily taken up by some plants. In mature leaf tissue of various plants, the normal range is 0.05-0.02 ppm; excessive or toxic levels range from 5-30 ppm. The amount of cadmium in soils is usually  $< 1$  ppm. Cadmium is added to the soil in wastes from alloys, fungicides, enamels, batteries, pigments, plastics, old motor oil, textile manufacturing, electroplating and rubber. Sewage sludges and some phosphate fertilizers also can be important sources of soil cadmium contamination. The principal use of cadmium is as an electroplated coating on fabricated steel and cast iron parts for corrosion protection; it is usually plated from a cyanide bath.



Cyanide, neither a metal nor a metalloid, is listed among the priority pollutants by EPA along with metals and asbestos. It may occur in metal-contaminated soil sites. Cyanides are extremely poisonous, readily reactive, and volatile, as hydrogen cyanide gas. In aqueous solution, cyanide forms hydrocyanic acid. Neutralization with bases (alkaline caustics such as sodium hydroxide) forms cyanide salts. The cyanide ion forms very stable complexes with a number of metals including titanium, vanadium, chromium, manganese, iron, cobalt, nickel, copper, molybdenum, palladium, silver, platinum and gold. Cyanides are highly toxic and act very rapidly. As a poison, cyanide functions very much like carbon dioxide. Hydrogen cyanide is the most used cyanide compound in industry. It is used in the extraction of silver and gold ores, to treat the surface of iron and steel, for electroplating of zinc, copper, brass, cadmium, and to a lesser extent, gold and silver, and certain other industrial processes, and as a pesticide for insects and rodents. Primarily, cyanide is used as a chemical intermediate in the production of methacrylates.

Manganese is accumulated in sediments and soils. Manganese is not generally considered to be a polluting metal in soils but its concentration can be increased when sludge is applied to soils. Its solubility in soils is highly dependent on pH and Eh; its mobility in soils depends entirely on its oxidation-reduction potential. In exceptional soils - those with a reducing environment, such as acid and peat bogs, it occurs as the bivalent form and migrates easily in the soil solution. The readily available and mobile bivalent form includes compounds that exist in soil solutions as carbonates, bicarbonates, sulfates and other easily soluble salts in acid soils up to pH 4.6. Hydrous oxides of manganese, as well as those of aluminum and iron are common in soils. They are found as crystalline minerals or as surface coatings and stains on other minerals. The hydrous oxides of both manganese and iron are very unstable because they are formed under oxidizing conditions, but dissolve under reducing conditions. The bivalent form in solution is difficult to oxidize.

Manganese forms trivalent compounds that are less mobile. In regions with a high oxidation potential, e.g., sandy and rocky deserts, and in the absence of organic matter and the action of solar radiation (sunlight) and other catalysts, bivalent manganese is changed to the quadravalent form, which is easily soluble in water and weak acid and can form concretions, hardpans, and stains, either separately or in combination with iron. Geochemistry of manganese hydroxides is closely related to behavior of iron hydroxides. Cross-interactions occur during redox reactions. It is particularly concentrated in soil horizons enriched with iron oxides and hydroxides. Organisms have an important role in the migration of manganese. Plants with long roots extract it from the subsoil. It is accumulated in the upper (O and A) horizons and in litter (fallen leaves). The distribution of manganese in the soil profile varies with thermic region. Many organisms, especially aquatic species, have the ability to concentrate manganese. Oxidation of bivalent manganese, and the reduction of high valence manganese compounds, is attributed largely to the activity of organisms.

Concentrations of manganese in surface soils generally vary from 1500 to 3000 ppm. Normal or sufficient levels in mature leaf tissues of various plant species ranges from 20 to 300 ppm; excessive or toxic levels range from 300 to 500 ppm. Manganese is used in steel, alloys, paint, dry cell batteries, glassmaking, metal treatment and as a chemical oxidizing agent.

Nickel has an unclear biochemical function, but is highly toxic to plants. In mature leaf tissue of various plants, the normal range is 0.1-5 ppm; excessive or toxic levels range from 10-100 ppm. In soils, it ranges from approximately 3.0 to 300 ppm and occurs primarily in the bivalent form. In sediments it is associated with iron and is absorbed on silicates. Nickel hydrates begin to form when the pH of the soil solution reaches pH 6.8. There are water-soluble compounds of nickel in soils. The amount of water-soluble nickel depends not only on the soil pH, but also the character of the subsoil. The vertical distribution of nickel in the soil profile is similar to that of iron. Total content in soil solution is -0.005 to 0.05 ppm. Nickel contamination of soil results from wastes such as batteries, paints, cosmetics, pigments, electroplating solutions, lacquers, cellulose compounds, steel and alloys, spark plugs and gasoline. The most important industrial use of nickel is as a hydrogenation catalyst, such as Raney nickel. The second largest use of nickel is in electroplating.

Tin in common rocks has the highest concentration in argillaceous sediments. Tin in soils is largely derived from the bedrock. It occurs in the divalent and quadravalent forms. Mobility during weathering is highly pH dependent. The divalent form is a strong reducing agent and is present only in acidic, reducing environments. Soluble tin has a behavior similar to that of iron and aluminum, including their hydroxides. It can form both soluble and insoluble organic complexes. Tin is fairly evenly distributed in the soil profile. Increased concentrations may be found in peats. Measurable tin is not found in all plant species. Tin is very toxic to both higher plants and fungi. Plants and crops grown on tin-contaminated soils can accumulate it. Mosses and sedges have been found to be excellent tin accumulators. Excessive amounts in mature leaf tissues may be approximately 150 ppm. The common range of tin in soils is 50 to 300 ppm. Higher values are found near tin mines and smelters. Tin wastes can include tin plating solutions used in the production of tinplate, and low-carbon steels and alloys coated with tin to reduce corrosion.

Thallium content of soils increases with weathering of acidic igneous rocks and increasing clay content of sedimentary rocks. In geochemical environments, thallium occurs in three oxidation states. The monovalent cation can be highly associated with potassium and rubidium. During weathering processes, thallium becomes readily mobile, but it is most often adsorbed by clays and gels of iron and manganese oxides. It can also be adsorbed by organic matter, especially under reducing conditions; higher concentrations of thallium may be found in surface rather than subsurface soils. The thallium concentration of plants is related to its concentration in

soils. Increased thallium levels in plant tissues are highly toxic to plants as well as animals and humans. Nitrate formation is inhibited in soils polluted with thallium. Normal concentrations of thallium in edible plants may range from 0.008 to 0.126 ppm. Herbaceous plants grown in thallium-enriched soils may accumulate > 100 ppm. Microorganisms may be relatively sensitive to thallium. The average thallium concentration for a number of soils is 0.1 ppm. Much higher concentrations are recorded near potassium fertilizer plants, smelters, and bituminous coal sites. Coal combustion is the principle source of anthropogenic contamination; heavy metal smelting and refining processes also release some thallium into the environment. Thallium compounds are used as pesticides, rat and ant poisons, in thallium mercury alloys, in the medical profession, as an ore-floating solvent, in low-melting glasses and semiconductors, and in fireworks. It is obtained as a flue-gas by-product during the production of sulfuric acid.

Mercury is strongly bound to humus, and is more strongly adsorbed under acid conditions. Strong interactions occur between mercury compounds and soil constituents. Its oxidation state is highly dependent on the soil redox potential. Through microbial transformations, metallic mercury can be readily converted to methylated or ethylated mercury. Methylated mercury (e.g., alkylmercury) will accumulate in the food chain and pose a resultant serious health hazard. Plants appear to have the ability to easily absorb mercury from solutions. It also appears that increases in the concentration of mercury in the soil also increases its concentration in plants. Plants can also adsorb mercury vapor. Symptoms of mercury toxicity include stunting of seedling growth, reduced root development and inhibition of photosynthesis. Displacement of mercury is more important in the vapor phase, where it is lost through volatilization. Amounts of mercury volatilized from the soil appear to be affected by the solubility of the mercury compound added to the soil. Volatilization is inversely related to soil sorption capacity and therefore texture, with losses from sand greater than those from loam, and more from loam than from clay. The common range of mercury in soil is 0.1 to 0.3 ppm. Mercury is added to the soil in wastes such as batteries, paints, plastics, fungicides, pharmaceuticals, paper products, manufacturing of electrical apparatus, and products of catalytic processes. The primary use of mercury is in electrical applications, secondarily in the electrolytic production of chlorine and sodium hydroxide.

Selenium, a nonmetal resembling sulfur in chemical properties, can have a metallic appearance but rarely occurs in the elemental form unless soil Eh is low. Most selenium in soils is in association with iron hydrates and concentrated by them. Normally, soils not derived from selenium-rich rock contain only a few ppm selenium. Toxic levels are reached at 5 to 10 ppm. In humid climates, selenium can be oxidized to the tetravalent form and readily migrates to ground waters. However, selenium in soil solutions is frequently reduced and can be precipitated in lower horizons. Selenium is least soluble under acid soil conditions. In acid soils selenium is

precipitated by ferric hydroxide and is probably a factor in reducing its mobility. Some western US. soils have toxic levels of selenium following successive years of irrigation, and selenium has migrated along with surface runoff and discharges. Lack of rainfall in arid areas may prevent the removal of selenium, but irrigation and leaching can lead to toxic levels in plants and waters and can be dangerous for animal life; selenium accumulation in plants may reach ~15,000 ppm. In mature leaf tissue of various plants, the normal range is 0.01-2 ppm; excessive or toxic levels range from 5-30 ppm. The common range of selenium in soils is 0.1 to 2 ppm. Selenium contamination occurs from wastes such as paints, pigments, and products of the electrical industry. Half of the selenium produced is used in the decolorization and production of colored glass, and in the production of calcium sulfide selenium pigments which are primarily used in plastics.

Zinc is usually associated with cadmium in naturally occurring soils. Its content in soil depends not only on the nature of the parent rocks and content of organic matter, but also on soil texture and pH. It is not as toxic as cadmium. Retention time of zinc in soils is similar to that of copper and is probably also greatly affected by the preferential uptake by vegetation. Zinc is considered to be relatively soluble and mobile compared to other heavy metals in soils. It is most readily mobile and available in acid light mineral soils. It may exist in excessive concentrations in some acid soils, leading to greater mobility. The zinc fraction associated with iron and manganese oxides is likely to be the form most available to plants. Acid leaching is important in zinc immobilization, with losses of this metal observed in certain soil horizons. Soluble zinc-organic complexes and complex anionic forms of zinc may account for the relative solubility and availability of zinc in soils with a high pH. Zinc content in soils is on the average twice that of copper and it is more uniformly distributed in soils than copper. Sewage sludge may be high in zinc. Zinc commonly occurs in soils at levels of 10 to 300 ppm, usually 30 to 150 ppm. In mature leaf tissue of various plants, the normal range is 27- 150 ppm; excessive or toxic levels range from 100 - ~400 ppm. Zinc is toxic to plants at ~400 ppm (dry weight). Certain endemic plant diseases can be attributed to the zinc content of soils. Zinc contamination in soils can result from additions of wastes such as paints, alloys, metal coatings, cosmetics, copying paper, rubber, linoleum and glass.

Other toxic metals or metalloids can include barium, and aluminum. Barium is toxic only in extreme conditions (e.g., barite mines). Aluminum, along with iron and manganese, can be toxic in acid soils. In general, almost any soil element is toxic to plants where it is present or available in abnormally high concentrations, restricts growth or is adsorbed by the plants, resulting in high tissue concentrations. Make comparisons with off-site concentrations in both plants and soils.

**VALUE:** Relatively nonmobile and nontoxic

**DEFINITION:** Residence time of the heavy metal in either the solid or liquid phase is relatively long, thereby generally decreasing potential toxicity.

**CONDITIONS:** Concentrations are found primarily as sorbed or fixed cations on soil minerals and organic matter and are dependent on soil properties such as pH and Eh. Mobility, and resultant toxicity, are therefore decreased or limited, unless soil particles are ingested. The metals or metalloids categorized here are arsenic, chromium, cobalt, copper, molybdenum, and silver. See individual descriptions for mobility and toxicity factors.

Arsenic is rather uniformly distributed in major rock types and has a great affinity to form or occur in many minerals. In contaminated soils, arsenates, such as from pesticides (sodium arsenate and arsenic trioxide) and sewage/industrial and mine wastes, are fixed in soils in a relatively insoluble state, and are not lost by leaching; they may accumulate. Arsenic can be troublesome in old orchards; concentrations of 2 ppm can be injurious to seedlings. Most plants contain <0.5 ppm (dry weight) of arsenic, but they may accumulate as much as 14 ppm. Mushrooms can accumulate relatively high concentrations of arsenic and can serve as "indicator" plants. Excessive or toxic ranges in various plants are 5-20 ppm. The arsenic content for a number of soils ranges from approximately 1 to 60 ppm. The lowest arsenic levels are found in sandy soils, and particularly those derived from granites.

Arsenic minerals and compounds are readily soluble, but migration is greatly limited because of strong adsorption by clays, organic matter and hydroxides. The mobility of arsenic in soil has been shown to be proportional to the amount of arsenic added, and inversely proportional to its residence in the soil and iron and aluminum content. The toxicity of arsenic depends considerably on the concentration of soluble arsenic. Yellow arsenic and arsenic compounds are highly poisonous if ingested. Arsenic is less toxic in soils with sufficient phosphorus. Sodium arsenate and arsenic trioxide, formerly used in herbicides, are the most toxic. Plant toxicity (phytotoxicity) of arsenic is highly dependent on soil properties. In heavy (clayey) soils, it has been found that very significant growth reduction occurs at 1000 ppm, but in light (sandy) soils, 100 ppm is equally toxic. Oxidation state of arsenic in soils is highly dependent on the redox potential. In heavy gley soil, arsenic is accumulated only in the top horizon. It is readily leached from the subsurface with a high reduction potential. In uncontaminated soils, the distribution of arsenic in the soil profile is highly variable. Other than pesticides, arsenic is found in wastes from a wide variety of processes and products: enamels, pigments, alloys, ceramics, lubricating oils, wood preservatives, fireworks, glass, printing and tanning processes, semiconductors and photoconductors. The major use of arsenic which results in hazardous wastes is the production of various chemical intermediates, secondarily for wood preservatives.

Chromium pollution of soils is seldom a problem except in mining and processing. It is not essential in plant nutrition and is rarely taken up by plants at usual prevailing soil pH and Eh (oxidation-reduction) values. Chemical forms of chromium in soil solution are not exactly known but it is expected that at pH range 5-7, most of the chromium is in the chromate form and would be complexed with various soil organic ligands. During disintegration and weathering of rocks, the trivalent form has little mobility, being similar to ferric iron. Under highly oxidizing conditions, such as in some hot desert soils, hexavalent chromate may form which is readily soluble, but this is an unusual phenomenon. Chromium is concentrated mainly in ultrabasic rocks, and particularly in serpentine-derived (magnesium silicate) rocks. The distribution of chromium in soils tends to follow that of iron. At low concentrations at low pH (< pH 4), it has little effect on plants, but in solution at high concentrations it can stop plant development. Most of the chromium absorbed by plants is retained in the roots. In mature leaf tissue of various plants, the normal range is 0.1-0.5 ppm; excessive or toxic levels range from 5-30 ppm. Chromium can be toxic to humans, especially if inhaled. At most soil pH and Eh levels, hexavalent chromium is reduced to trivalent chromium. Hexavalent chromium predominates at pH 6 and as dichromate ions at pH 2 to 6. Trivalent chromium is the stable form in soils. Industrial chromium includes organically complexed trivalent chromium which may remain mobile in soils. It is mobile in the hexavalent form, and can be highly toxic in this form. The reduced trivalent form is less mobile. Hexavalent chromium is the major form of chromium used in industry. It is found in wastes such as steel and other alloys, chrome plating, electroplating, varnishes, dye fixers, corrosion inhibitors, photography emulsions and defoliants. Sodium dichromate is the primary raw material for the production of other chromium chemicals, both trivalent and hexavalent forms. These compounds are largely used for chromic acid and chrome pigments.

Cobalt is associated with various iron minerals and in geochemical cycles, it closely resembles iron and manganese. Its distribution in sediments in the soil profile is strongly related to manganese oxides. Cobalt sorption on soil particles/clay minerals is preferential. It is fixed or combined with large molecules such as in humus. Trivalent cobalt forms complex organic compounds and is dispersed through soils in the crystal lattices of aluminosilicate minerals. Hydrates of cobalt form when the pH of the soil solution reaches pH 6.8. The amount of available cobalt is related to the amount of available (acid-soluble) iron. There are some water-soluble compounds of cobalt in soils, but the amount available also depends on soil pH and subsoil characteristics. Cobalt accumulates in the humic horizons of many soils. It is easily solubilized and mobile in peaty soils. The vertical distribution of cobalt in the soil profile is similar to that of iron. In mature leaf tissue of various plants, the normal range is 0.02-1 ppm; it can be toxic to plants. Excessive or toxic levels range from 15-50 ppm, approximating those levels which are considered excessive in soils. Cobalt and its salts are obtained chiefly as by-products in the metallurgy of nickel. It is found in steel and alloys and is widely used in catalytic processes.

The content of copper in natural soils depends largely on the nature of the parent rock. The most important sources of copper in soils are copper-bearing sandstones and deposits of copper minerals, e.g., malachite, chalcopyrite, etc. Copper is toxic to most plants in soil solutions exceeding 0.1 ppm; the oxidized form is the nutrient source for plants; solutions > 20 ppm can be toxic to animals; solutions of 1.0 ppm are safe for drinking water; normal soils are ~20 ppm. Mobility and displacement of copper is low because of its strong bonding with organic matter and clay minerals. It is principally complexed with organic compounds of low molecular weight. If the soil organic matter undergoes anaerobic (reducing) decomposition, copper can be released in the monovalent (cuprous) state; under aerobic (oxidizing) conditions, copper can be released in the divalent (cupric) state. Root tissues have a strong ability to retain copper. The retention time for copper in soils is much shorter than for lead, despite similar heavy metal-organic matter constraints, probably due to preferential uptake as a micronutrient by plants. In mature leaf tissue of various plants, the normal range is 5-30 ppm; excessive or toxic levels are 20-100 ppm. Some lichens occur on substrates high in copper. Surface soils have a great ability to accumulate copper. The average range in soils is 2-100 ppm. Copper contamination in soils results from agricultural copper-containing materials such as fertilizers, pesticide sprays, agricultural or municipal wastes and industrial emissions.

Lead occurs naturally in soils from the composition of the parent rocks, but it may accumulate in the surface horizons of soils and organic matter, particularly in soils along roads from traffic exhausts, from lead-zinc smelters, from use of old insecticides, and from dumps and other sites receiving industrial/household lead (e.g., old paints, batteries). Mobility of lead in soils and plants tends to be low; in soils it is considered to be the least mobile among the heavy metals and on the basis of mobility would not be considered toxic. Lead occurs mainly in the divalent form. It has the ability to replace potassium, barium, strontium and calcium in soil mineral and adsorption sites. More lead is naturally found in surface organic soils than in mineral soils, and therefore migration can occur more easily than in mineral soils. Organic matter should be considered the most important sink of lead in contaminated soils. Natural soils may contain as much as 10 ppm total lead. Lead can cause diseases in animals, and although lead is a serious health hazard, uptake is by surface contamination and by accidental ingestion of contaminated soil; crops, and grasses (eaten by animals), and not by plant uptake. Normal lead levels in various plants range from 0.5 to 3 ppm. Some lichens occur on substrates high in lead. Roadside concentrations may be as high as 2400 ppm. Waste dumps may contain lead from old paints, batteries, pesticides, solder, glass, brass, bronze, pigments and ammunition.

Molybdenum is higher in soils derived from granite and shale. Molybdenum is usually deficient in most U.S. soils. Mobility depends largely on soil pH, Eh, organic matter, humus, drainage, and other factors. Molybdenum in wet alkaline soils is most easily taken up by plants. Easily mobile anions are readily coprecipitated by organic matter

and calcium carbonate. It is least soluble in acid soils and readily mobilized in alkaline soils. Differential adsorption of molybdenum by iron, aluminum and manganese hydrous oxides contributes to the retention of molybdenum in surficial deposits. Its solubility decreases with time. Plants take up molybdenum mainly as molybdenite ions. Its absorption is proportional to its concentration in the soil solution and is a function of soil pH, especially pH 6 to 8. Plant uptake is increased at sites contaminated with molybdenum. Toxicity symptoms are definitely apparent in plants at > 200 - 300 ppm (dry matter), although lower levels of 10-15 ppm have also been found to be toxic or excessive. Toxicity symptoms in plants under field conditions is rare. The normal range in mature leaf tissue of various plants is from 0.2-1 ppm. In surface soils, the usual range for various soils is 0.8 to 3.3 ppm with a mean of 2.0 ppm, closely resembling that of the parent rocks. Molybdenum is used in steel making and in magnets, such as telephone receivers.

Silver is easily released by weathering and is then precipitated in alkaline reduction potential media or in media enriched with sulfur. Its geochemical characteristics are similar to those of copper. Its concentration in rocks is less than 1,000 times that of copper. It forms several complexed anionic and simple cationic species. Despite several mobile complexes, it is relatively immobile in soils at > pH 4.0. Humic substances absorb and complex silver, which can lead to an enrichment of surface soils (A and O horizons). Silver concentrations differ greatly among plant species and times of sampling. The amount of silver absorbed by some higher and lower plants can be related to the amount of metal in the soil. It can be concentrated to toxic levels in plants growing in silver-mineralized areas. Silver in mature leaf tissues of various plant species is usually approximately 0.5 ppm. Excessive or toxic levels reach 5 to 10 ppm. The common range of silver in soils is 0.03 to 0.09 ppm. Silver contamination of soil can result from photographic and electroplating wastes and mirror manufacturing. Silver is primarily consumed in the form of silver nitrate and silver halides for photographic processes, as silver cyanide complexes and for electronic product contacts and conductors. Because silver is a precious metal, usually every economic effort is made to reclaim it before products are disposed.

Make comparisons with off-site concentrations for all suspected abnormal concentrations in total soils or soil solutions; determine mobility and uptake, if necessary.

Table 3-1 below summarizes the ranges of metals considered to be excessive as compared to analyses obtained for many uncontaminated soils and various plants. Specific soil, soil solution, soil extract, plant analyses and toxicity tests with metal species are needed for these determinations. Table 3-2 provides information on the toxicity of a simulated solid waste leachate (USEPA, 1982).



Table 3-1. Concentration of Metals and Nonmetals (Trace Elements)  
 Considered to be Phytotoxically Excessive  
 Levels in Surface Soils and Various Plants in ppm Air Dry Weight (10,000 ppm = 1 %).<sup>a</sup>

Element	Surface Soil <sup>b</sup> Acid-Neutral	Plant <sup>c</sup>	Relatively Mobile <sup>d</sup>	Relatively Toxic <sup>d</sup>
Antimony (S b)	5-10	150	+	-
Arsenic (As)	100- 1000	5-20		
Beryllium (Be)	> 10	10-50		+
Boron (B)	30-100	>500	+	
Barium (Ba)	30-100	50-200		
Cadmium (Cd)	3-10	5-30	+	+
Cobalt (Co)	30-50	15-50		
Chromium (Cr)	2-10	5-30		
Copper (Cu)	20-100	30-100	+	
Mercury (Hg)	1-5	1-3	+	+
Manganese (Mn)	3000-8000	300-500	+	
Molybdenum (Mo)	5-10	10-50		
Nickel (Ni)	30-100	10-100	-	+
Lead (Pb)	50-100	30-300	-	+
Selenium (Se)	5-10	5-30	+	+
Silver (Ag)	> 2	5-10	-	-
Thallium (Tl)	---	>20	+	+
Tin (Sn)	> 50	>60	+	-
Zinc (Zn)	200-400	100-400	+	+

<sup>a</sup> After A. Kabata-Pendias and M. Piotrowska, 1983, and A. Kabata-Pendias and H. Pendias, 1984.

<sup>b</sup> Range for coarser textured and acidic soils (CEC=5-10 meq/100 g), and for clayey, finer- textured, and more neutral soils (CEC= 10-20 meq/100 g), respectively.

<sup>c</sup> Range for premature plant tissue for various species that are not sensitive or have developed tolerance.

<sup>d</sup> Relative mobility in soils and toxicity to plants, animals or humans. Metal and metalloid species vary in their mobility and toxicity depending on their form (ion), and related factors of soil pH-Eh, texture, structure, mineralogy, oxides and hydroxides, presence of various cations and anions, organic matter content, temperature, moisture content and potentials, porosity, microbial abundance, kinds, activities, etc. See knowledge frame on nature of heavy metal soil pollutants for comments on specific metals and metalloids.

TABLE 3-2 BEHAVIOR OF METALS DURING VARIOUS WEATHERING PROCESSES<sup>a,b</sup>

Degree of Mobility	Soil pH-Eh	Metals and Metalloids
High	Oxidizing and acid	Boron
	Neutral or alkaline	Boron and selenium
Medium	Oxidizing and acid	Molybdenum, selenium and zinc
	Mainly acid	Cadmium, cobalt, copper, mercury and nickel
	Reducing with variable potential	Arsenic, cadmium, cobalt, chromium, iron, manganese and tin.
Low	Oxidizing and acid	Barium, beryllium and iron
	Neutral or alkaline	Barium and beryllium
Very low	Oxidizing and acid	Chromium
	Neutral or alkaline	Silver, copper, cobalt, nickel, thallium and mercury
	Reducing	Silver, barium, beryllium, cobalt, copper, boron, mercury, molybdenum, nickel, selenium and zinc.

<sup>a</sup> After A. Kabata-Pendias and H. Pendias, 1984.

<sup>b</sup> The mobility of these elements during weathering processes is determined (1) by the stability of the parent minerals and (2) by the electrochemical properties of the elements.

TABLE 3-3 EPA TOXICITY LEVELS OF EXTRACTED HAZARDOUS WASTE SAMPLES CONTAINING METALS, METALLOIDS AND ORGANICS<sup>a</sup>

Compound	Maximum Concentration (mg/L)
Arsenic	5.0
Barium	100.0
Cadmium	1.0
Lead	5.0
Mercury	0.2
Selenium	1.0
Silver	5.0
Endrin	0.02
Lindane	0.4
Methoxychlor	10.0
Toxaphene	0.5
2,4-D (2,4-Dichloro-phenoxyacetic acid)	10.0
2,4,5-TP Silvex (2,4,5-Trichlorophenoxypropionic acid)	1.0

<sup>a</sup> US EPA, 1982. Test Methods for Evaluating Soil Waste - Physical/Chemical Methods, 2nd ed. Office of Solid Waste and Emergency Response, Washington, D.C.

Toxicity levels for heavy metals not included on the above EPA List include the following:

Compound	Maximum Concentration (mg/L)
Beryllium	2.0
Cobalt	5.0
Copper	0.1
Iron	5.0
Manganese	3.0
Molybdenum	40.0
Nickel	5.0
Tin	300
Zinc	1.0

The California List of regulations banning land disposal of specified hazardous wastes or liquid hazardous wastes (including free liquids associated with any solid or sludge), requires that they cannot contain  $\geq 1,000$  mg/l of free and complex cyanides.

OBJECT/ATTRIBUTE: SITE/CLIMATE AND WEATHER

DEFINITION: Climate: the average course or condition of the weather for the site and region over a period of years as exhibited by temperature, meteoric precipitation, and wind.  
Weather: the state of the atmosphere at the site and region during the time of study with respect to heat or cold, wetness or dryness, calm or storms, clearness or cloudiness, and barometric pressure.

VALUES: HUMID  
TEMPERATE  
DRY

CATEGORY: SITE BACKGROUND

PROPERTIES: INPUT FACT

REFERENCES: Koeppel and Delong, 1958  
National Climate Data Center, 1983  
Shaw, 1967  
Stephens and Stewart, 1964  
Thornthwaite and Mather, 1957  
Trewetha and Horn, 1980  
USDA Soil Conservation Service, 1970, pp. 27 - 28

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VALUE: Humid

DEFINITION: A general category for a climatic regime that is usually hot or warm and not dry for more than a 2-month period. Weather usually rainy.

CONDITIONS: Climate and weather-related measurements for a site are important in regard to soil and plant development, weathering, fate, transport and deposition of contaminants, effects on field instruments (their operation and measurements), and sampling. Weather and/or meteorological measurements related to the site include cloud cover - its nature, extent and duration and as it affects solar radiation, absorptivity and reflectivity, temperature, precipitation (meteoric), barometric pressure, humidity (relative humidity), dew, wind direction and velocity. Additional site measurements, which can characterize the site can include evaporation rate and its relationship to diffusion, volatilization and evaporation of water or liquid chemicals and contaminant solutes from the soil surface, evapotranspiration and net thermal exchange, which are soil-plant (and animal) - microclimatic relationships. Also see knowledge frame for

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wind direction and velocity, temperature, temperature regime and vegetation, macro and mesofauna.

Climate, interacting with parent materials and vegetation, is an overriding factor in soil development, formation and resultant properties (e.g., high organic matter, leaching, and high acidity). Usually, there is a resultant dense vegetation of trees and shrubs or grasses at constant temperatures and increase in moisture; both plant growth and clay content will increase. At constant moisture, the clay content increases along with plant growth. Soil sampling is difficult because of vegetation, either because of surface growth or roots, surface litter, or organic matter except in cleared areas and where soil structure has been altered or destroyed by soil disturbance such as through crust formation, puddling, compaction, etc. Sampling also may be difficult if soil is wet. Removal of vegetation increases soil temperature evaporation and net thermal exchange and reduces soil moisture, especially in the tropics. Much of water and chemicals will percolate through the soil with considerable leaching of soluble minerals and metal ions.

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VALUE: Temperate

DEFINITION: A climate regime common in middle latitudes, affected by either ocean or continents, westerly winds and rain in all seasons, or winter snow.

CONDITIONS: Climate is still an important factor in soil formation, although forests may be less dense and extensive grasslands may be present. Soils are less leached than are those in humid regions; they exhibit less (but still significant) organic matter and moderate percolation. A moderate amount of water and chemicals are subject to leaching and percolation through the soil. Weather may vary seasonally and diurnally. Check with local weather station before sampling for temperature, wind, and meteoric precipitation (rain).

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VALUE: Dry

DEFINITION: A dry climatic regime not dependent on temperature, where a deficiency of precipitation is the dominant climatic characteristic.

CONDITIONS: Arid, semi-arid, and desert types are found. The boundary separating hot from cold dry climates is the isotherm of 8 months with a temperature of 10°C (50 °F) or above. There may be a short moist season, meager rainfall during most of the summer, or the region may be constantly dry.

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Climate has less effect in soil formation than other factors; parent material and minerals are predominant factors. Most of the retained water or chemicals are held by the soil minerals. There is very little or no leaching; soils are generally alkaline. Trees, shrubs, and grasses are sparse or scattered except in favorable habits, with xeric varieties, or non-existent in extreme dryness or where removed through human or animal activities. Erosion and rapid runoff are noticeable. Transport of surface chemicals is largely dependent on sudden downpours and on management practices. Check with local weather station in case inclement weather is expected at time of sampling. Sampling also may be difficult if soil is too hard.

OBJECT/ATTRIBUTE: SITE/SLOPE

DEFINITION: The surface properties of the soil in terms of gradient, complexity, configuration, length, and aspect; a property of the soil, not a landform.

VALUES: STEEP  
MODERATE  
LEVEL TO NEARLY LEVEL

CATEGORY: SITE BACKGROUND

PROPERTIES: INPUT FACT

REFERENCES: Blakely, et al., 1957  
Mason, 1983b, pp. 5-20  
USDA Soil Conservation Service, 1981 pp, 4-6 to 4-9; 4-95

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VALUE: Steep

DEFINITION: A slope class of >12%; gradient, complexity, configuration, length, and aspect are high.

CONDITIONS: Slope characteristics greatly affect the distribution, infiltration and subsequent percolation of soil water and surface runoff. Slope gradient, the length and shape of slope along with slope aspect and the topographic position, e.g., mountain, lowlands or floodplain, are important site features to note.

CONDITIONS: Steep slope characteristics greatly reduce the retention and infiltration of liquids. Rate and amount of runoff is rapid; movement of soil and other materials is high; potential for soil slippage and acceleration of erosion is high. For every doubling of steepness of slope, loss of soil and other materials are increased by 2.5 times. Slope aspect is important; in the northern hemisphere north-facing slopes are cooler and exhibit lower evapotranspiration than south-facing slopes. Slope aspect is still important at high latitudes and in areas where winds are high, with corresponding evapotranspiration, and where there is an increased rate and amount of solute removal, including soluble contaminants.

VALUE: Moderate

DEFINITION: A slope of 3 to 12%. Slope effects are not as high as for a steep slope.

CONDITIONS: Length of slope and associated factors are still important. The longer the slope, the more soil materials and liquids are lost. If the length of slope is doubled, soil loss is generally increased 1.5x. Effects of soil internal properties and surface characteristics increase relative to penetration rate or to runoff and deposition of sediment.

VALUE: Flat to nearly level

DEFINITION: A slope of 0 to 3%.

CONDITIONS: Slope effects are of decreased importance, with decrease in rates of runoff, erosion, and removal of sediment. However, the relatively flat areas receive sediments from the steeper slopes and can, therefore, accumulate transported metal contaminants. Soil configuration and internal properties are more important with increased infiltration, penetration, and retention of water and chemicals. Volumes of chemicals and rainfall are of increased importance for retention and movement of liquids.

Table 3-4. Definitions of Slope Classes. (from the Soil Conservation Service, 1981)

Classes		Slope gradient limits	
Simple Slopes	Complex Slopes	Lower %	Upper %
Nearly level	Nearly level	0	1-3
Gently sloping	Undulating	1-3	5-8
Strongly sloping	Rolling	5-8	10-16
Moderately steep	Hilly	10-16	20-30
Steep	Steep	20-30	45-65
Very steep	Very steep	45-65	None

Slope classes are largely determined from slope gradients. A slope gradient is the inclination of the soil from the horizontal generally measured with a hand level. The difference in the elevation between two points is then expressed as a percentage of the distance between those points. If the difference in elevation is 1 m over a horizontal distance at 100 m, the slope is 1%.



OBJECT/ATTRIBUTE: SITE/SURFACE EROSION AND ERODIBILITY

DEFINITION: Erosion: wearing away of the soil or land surface by running water, wind, ice, or other geological agents, including such processes as gravitational creep. Erodibility: the vulnerability or degree of susceptibility of soil to erosion processes.

VALUES: SEVERE  
MODERATE  
SLIGHT TO NONE

CATEGORY: SITE BACKGROUND

PROPERTIES: INPUT FACT

REFERENCES: Blakely, et al., 1957  
Chepil, 1957  
Mason, 1983b, pp. 5-26 to 5-28; 5-38 to 5-39  
USDA Soil Conservation Service, 1975  
USDA Soil Conservation Service, 1981, pp. 4-19 to 4-27  
Wischmeir and Smith, 1978  
Woodruff and Siddoway, 1965

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VALUE: Severe

DEFINITION: Surface soil highly susceptible to erosion; surface soil and rock materials severely eroded, detached and transported through the action of water, wind, and other geologic agents. Estimated annual soil loss is 10 to > 25 metric tons/hectare.

CONDITIONS: Natural erosion is an important process that affects soil formation and/or the establishment of a vegetative cover. Man-induced influences may accelerate erosion, also by the two processes of classes of erosion, wind and water. Wind erosion is important primarily, but not exclusively, in subhumid, semiarid, and desert regions. Water erosion is important in humid regions, but is also important as an eroding agent in arid regions. (Also see the knowledge frame on soil temperature regimes.) In the field, surface erosion may be assessed as the amount of soil lost or deposited in the past at the site. Erodibility may be estimated as the future or potential for erosion. The Soil Conservation Service should be contacted for details on erosion and erodibility.

Soil and surface materials are easily subject to removal by sufficient velocities of wind and water, or show signs of such removal, especially where soils are barren and

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fine-textured, either through natural processes (e.g., aridity), or disturbance. The original surface soil has eroded away or can only be identified in spots. Removal or depletion of vegetation and vegetative cover is the main cause of the wind erosion. Alternate wetting and drying, freezing and thawing tend to break down soil aggregates to granules that are highly erodible. Poor management factors can promote erosion. Soil loss by runoff per unit area generally increases substantially with length and steepness of slope. Adequately designed waterways will greatly reduce runoff and erosion and may be the single most important control factor, other than vegetative cover. In cultivated agricultural areas, soil management is an important factor, especially tillage operations, such as contour tillage, contour terraces, etc.

The Universal Soil Loss Equation (USLE), or revised version (RUSLE) may be used to estimate potential erosion from a site, particularly as related to agriculture. The USLE considers both wind and water erosion. Field observations should include slope gradient and length (see knowledge frame for slope) and vegetative cover (or crop). Additional information, such as the erodibility factor, should be obtained from the SCS. The wind erosion equation also may be useful for predicting the average annual loss of soil due to wind. These two equations are given below:

*Universal Soil Loss Equation (USLE)* - An equation for predicting  $A$ , the average annual soil loss in mass per unit area per year, and is defined as  $A = RKLSPC$ , where  $R$  is the rainfall factor,  $K$  is the soil erodibility factor,  $L$  is the length of slope,  $S$  is the percent slope,  $P$  is the conservation practice factor and  $C$  is the cropping and management factor.

*Wind Erosion Equation* - An equation for predicting  $E$ , the average annual soil loss due to wind in mass per unit area per year, and is defined as  $E = IKCLV$ , where  $I$  is the soil erodibility factor,  $K$  is the soil ridge roughness factor,  $C$  is the local climatic factor,  $L$  is the field width, and  $V$  is the vegetative factor.

Chemicals that destroy vegetation will promote erosion as well as runoff. Severe erosive forces increase the potential for removal and dispersion of applied contaminants and limit their potential for subsurface penetration and accumulation.

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VALUE: Moderate

DEFINITION: Surface soil is moderately susceptible to erosion; surface soil and rock materials show some evidence of erosion. Estimated annual soil loss is 2.5 to 10 t/ha.

CONDITIONS: Soil and surface materials are less subject to removal except by high and long-duration velocities of wind or water. Surface effects of erosive forces are evident, but reduced through moderating properties of soil, topography, and vegetation. The natural surface soil may still have lost a considerable amount of material of the surface horizon or top 10 to 12 inches (~20 to 25 cm). Applied chemicals, depending on their nature (e.g., viscosity), may promote some soil properties to reduce erosion/erodibility (e.g., promotion of aggregation and adhesion), or increase potential for erosion/erodibility, damage or destruction of vegetative cover.

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VALUE: Slight to None

DEFINITION: Surface soil is only slightly or undiscernibly susceptible to erosion, temporally or spatially; surface soil and other surface materials show little evidence of erosion. Annual soil loss is < 2.5 t/ha to zero.

CONDITIONS: Soil surface materials are little affected or are otherwise protected from erosive forces of either wind, water or other geologic forces. Climate/weather (humid/moderate), soil properties, and surface features, topography and vegetation (nature, extent and depth) are favorable factors to reduce or ameliorate erosion/erodibility. Applied chemicals will have reduced potential for soil and chemical removal and transport by erosive forces of wind and water. Potential for penetration and subsurface infiltration, movement, and accumulation is increased.

OBJECT/ATTRIBUTE: SITE/SURFACE POLLUTION SITUATIONS

DEFINITION: Contamination of the soil with various harmful compounds and materials primarily introduced by human activities.

VALUES: LARGE AREAS  
LOCALIZED AREAS

CATEGORY: SITE BACKGROUND

PROPERTIES: INPUT FACT

REFERENCES: DeHaan and Bolt, 1979  
Mason, 1983, Appendix 3, pp. 9-12  
Sims, 1986

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VALUE: Large Areas

DEFINITION: The pollutant covers a wide area, primarily on the surface.

CONDITIONS: The pollutant usually covers an area large enough to encompass a variety of parent materials, a number of soil "types" (map units) with varying soil properties, various topographic features, slopes, aspects, and kinds and distribution of vegetation. The major pollutant source may have been present for a short time, with appropriate survey studies made by ambient monitoring. The effects and extent of pollution may be ameliorated over a longer period. Pollutants may have migrated into the soil as much as 1 to 2 feet (30.5 cm - 61 cm). Where significant organic matter is present, penetration may be lessened to only a few inches or cm, but chelation with organic matter (humus) may mobilize metal ions and they may be attenuated with depth in the soil solution. Movement of heavy metals through soils is largely dependent on the organic matter content of the soil. The greater the organic matter content of the upper horizon of soil, the greater the affinity of that horizon for heavy metals. Stratified sampling may be desirable, with a large number of samples taken. Hand tools can usually be used to collect samples.

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VALUE: Localized Areas

DEFINITION: Areas usually polluted near the source.

CONDITIONS: These areas are usually affected by spills resulting from industrial or transportation accidents, fires, explosions, or unexpected leaks from storage containers. Polluted areas cover less area, with only a few differences in parent material, soil "types" and properties, surface features, and vegetative features. The polluted area may be more readily identified from the unaffected area because of noticeable differences in color, odor, and effects on other soil properties and site vegetation. Sampling may be more rapidly performed than for large affected areas. Grid, simple random sampling, and, in some specialized cases, stratified sampling may be performed. Samples usually are collected with a core sampler and can be composited in some cases, unless organic contaminants (volatiles and semivolatiles) also must be considered for analytical purposes.

## OBJECT/ATTRIBUTE: SITE/SURFACE RUNOFF

DEFINITION: That portion of the meteoric precipitation on an area of soil or land surface discharged from the area through natural or manmade stream channels.

VALUES: RAPID  
MEDIUM  
SLOW  
PONDED

CATEGORY: SITE BACKGROUND

PROPERTIES: INPUT FACT

REFERENCES: Mason, 1983a  
USDA Soil Conservation Service, 1981, pp. 4-34 to 4-35, 5-15 to 5-20; 5-41 to 5-42; A5-55 to A5-79

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VALUE: Rapid

DEFINITION: Surface water or liquid chemicals flow so fast that the period of concentration is brief and free water or chemicals do not stand on the surface.

CONDITIONS: The soils are frequently moderately steep to steep (about 10% slope or greater) and rates of penetration and infiltration are slow. Slope shape, whether convex, concave or complex and topographic position are important. Other soil surface properties, such as crusts, compaction and cementation, high clay content and hydrophobic salts will increase runoff and transport of sediments and applied contaminants, including metal species. High viscosity of the liquid chemicals will provide for increased flow rate and runoff. Also see knowledge frame on infiltration and percolation.

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VALUE: Medium

DEFINITION: Surface water or liquid chemicals flow away fast enough so that free liquids stand on the surface for only short periods.

CONDITIONS: The surface soils are less steep, and nearly level or gently sloping (0 - ~10% slope) and absorb liquids at a moderate rate, or they are steeper but absorb liquids rapidly. Part of the liquids, depending on viscosity, will enter the soil, but they also are subject

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to evaporation or movement along subsurface channels. Migration of medium-velocity chemicals on the surface will be moderate. High intensity of rainfall or application of hydrophobic liquid chemicals will increase runoff, as will frozen, compacted, or cemented soil, and other soils with lesser degree of infiltrability.

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VALUE: Slow

DEFINITION: Surface water or liquid chemicals flow away slowly, and may stand freely on the surface for moderate to long periods.

CONDITIONS: Liquids immediately or rapidly enter the soil, pass through it, or evaporate. Soils are very gently sloping (< 5%), nearly level or level (0 - 3% slope), very open and porous, and do not impede infiltration and penetration of liquids. Surface conditions provide greater potential for retention of contaminants.

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VALUE: Ponded

DEFINITION: Little of the rainfall, runoff, or liquid chemicals escape as runoff, and they freely stand on the surface for significant periods.

CONDITIONS: The quantity of liquids removed from ponded areas is by evaporation, by gradual movement through the soil, or possibly by plants unless physically removed by mechanical means (e.g., siphoning). Evaporation is usually greater than the total rainfall, but may not exceed that of applied chemicals, especially of low viscosity. Ponding normally occurs on level to nearly level depressional soils. Tight, clayey, nonporous soils, compactions and pans in depressed soil will increase ponding until depressions are filled. Depth of liquids may fluctuate greatly, with considerable potential for infiltration and accumulation at subsurface depths.

## OBJECT/ATTRIBUTE: SITE/VEGETATION

DEFINITION: The nature, kind, extent and distribution of plants and plant cover for a given, designated site.

VALUES: DENSE  
SCATTERED TO SPARSE  
ABSENT

CATEGORY: SITE BACKGROUND

PROPERTIES: INPUT FACT

REFERENCES: Cruickshank, 1972, pp.101-154  
Ricklefs, 1979, pp. 27-202  
Shaw, 1989  
USDA Soil Conservation Service, 1981, pp. 4-10 to 4-12  
US DOE, 1987, pp. E-179 to E-184  
Vogel, 1987

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VALUE: Dense

DEFINITION: Site completely covered with vegetation of predominant forms or varying in composition and distribution of species, usually with slow temporal variability.

CONDITIONS: Inputs to an ecosystem or site from existing vegetation occur in a number of ways; inputs from above-ground biomass, inputs from roots and other below-ground biomass, and leaching and washoff from leaf surfaces. These inputs are also considered fluxes within the ecosystem. The lead concentration of most vegetation is relatively low despite evidence that it is probably as much as five times higher than prior to industrialization. In forested sites under a variety of conditions in Europe and North America, the amounts of lead, cadmium, and nickel in vegetation are somewhat lower than the amounts of the same metals in soil. Near smelters, vegetation levels of most metals are quite high.

Generalizations about the behavior of heavy metals in relation to vegetation is difficult. Metals that are clearly harmful to vegetation are generally excluded from uptake by roots or through foliage. However, other heavy metals that may be considered essential to plants are micronutrients (e.g., copper, zinc) which may behave more like macronutrient elements with respect to their cycling rates and accumulation patterns. Vegetation is usually the first interceptor of heavy metals deposited to an ecosystem.

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However, if the ecosystem is sparsely vegetated, soils may be the first interceptor of heavy metal deposition. Heavy metals in water contacting vegetation may be (1) adsorbed to vegetative surfaces; (2) absorbed into the cuticle or leaf; or (3) relatively unaffected by vegetation. If metals are adsorbed onto leaf and other vegetative surfaces, they may be remobilized later by water. Depending on the element leaching from foliage, and washoff of dry deposited material, there may be an influence on the net change in heavy metal flux above and below a vegetative cover or canopy.

Some heavy metals, such as iron, manganese, zinc, copper and molybdenum are essential micronutrients. Others, such as arsenic, aluminum, cadmium, chromium, mercury and lead are not essential. Regardless of whether they are biologically essential or not, a common characteristic of heavy metals in general, is that they may already exert toxic effects in low concentrations, compared with macronutrients. Many plant essential micronutrients which are heavy metals, i.e., copper, iron, manganese, and zinc, can be toxic to plants encountered in natural, uncontaminated ecosystems. Local enrichment of heavy metals in soils, either through natural processes (geochemical anomalies) or human activities (exploitation of mineral resources), usually coincides with increased resistance levels in plants. Metal resistance is typically a quantitative characteristic, correlated with the prevailing metal availability levels in the soil. Metal resistance is usually highly metal specific and confined to those metals often associated with co-occurrence of high levels of these metals in the soil. However, some resistant plants may also show a degree of resistance to metals only present at low nontoxic levels. Many resistant plants exhibit an increased need for certain metals to which they are resistant, as expressed by a less than maximal growth at "normal" availability levels.

Vegetation cover may show predominant species of trees and canopy, shrubs, grasses, and forbs (weeds). Soil vegetation cover may include algae, mosses, lichens, and liverworts. Potential for runoff and erosion is greatly retarded, especially with extensive soil vegetative cover. The efficiency (effects) of plants and their effects by site pollutants should be noted, such as damaged plant parts, and effects on growth, reproduction, and distribution. Plant species distribution, location, and proximity to a pollutant source, and the condition of plant parts should be noted and recorded. Some plants may not show visible effects and appear to be "healthy," although pollutant uptake may have occurred. Compare with analyses of various soil metal contaminants and adjacent or off-site vegetation. It may be desirable to collect plant parts and soils for further studies including plant tests for foliar analyses. Photographs should be taken to show aerial and soil surface plant cover distribution and any unusual plant features. Plant cover should be cleared or removed from sampling sites to expose surface soil. Plant parts may be retained for further analyses.

VALUE: Scattered to Sparse

DEFINITION: Plant cover, aerial or soil surface vegetation, is intermittent or infrequent at the site.

CONDITIONS: Observations should be made of species, distribution, and other plant features, especially in comparison with the unaffected, nonpolluted area surrounding or adjacent to the site. Any differences should be noted, recorded and photographed. Any unusual stands, distribution, or unhealthy condition of plants should be related, if possible, to the pollutant, site, and soil disturbance. Compare with the unaffected, noncontaminated area off-site vegetation.

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VALUE: Absent

DEFINITION: No visible macrovegetation can be observed, but some scattered soil vegetative cover may be evident, e.g., algal-lichen crusts or mosses.

CONDITIONS: Compare absence of vegetation with that of adjacent and surrounding site. Significant differences should be noted, recorded and photographed. Age of site, site disturbance, runoff, erosion, infiltration, penetration, hydraulics, and pollutant source and characteristics should be noted for any effects on absence of vegetation. Compare with analyses for various soil-contaminating heavy metals and effects on any off-site or adjacent vegetation.

OBJECT/ATTRIBUTE: SITE/WIND SPEED AND DIRECTION

DEFINITION: Natural movement of air of any velocity. Speed: the velocity of the wind measured in knots or miles per hour. Direction: one or more of sixteen points of the compass with relation to the point of observation of the wind.

VALUES: GALE  
BREEZY  
CALM TO LIGHT

CATEGORY: SITE BACKGROUND

PROPERTIES: INPUT FACT

REFERENCES: Cantzlaar, 1964, pp. 133-141  
Ford and Turina, 1983, pp. 7-29  
Koepe and Delong, 1958, pp. 81-88  
Lehr, et al., 1975

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VALUE: Gale

DEFINITION: Wind Speeds are 32 MPH or higher (> 37 knots); arc of wind direction may not shift or shift more than 180°.

CONDITIONS: Climate data and weather reports should be consulted for seasonal and/or daily wind patterns, velocity and direction. Wind is important in erosion and removal of site contaminants (see knowledge frame on erosion) and especially at time of sampling. The following information pertains to wind characteristics primarily prior to, and during the sampling sequence. Average, as well as peak values should be noted.

Use hand-held anemometer or wind vane, if available. Continued monitoring of wind speed and direction should be undertaken during sampling. Wind direction indicators (4-ft. staff with 18-in. flag or flagging tape) should be placed throughout the operations area. Conditions at the site show strong indications of wind velocity or changes in direction. Whole trees are in motion; walking or working in the wind is inconvenient; light, loose objects are lifted from the ground; a flag or cloth will whip about wildly or will violently change direction. Sampling should be postponed. Check with local weather station for forecasts. (By international agreement, all reports for use in plotting weather maps use knots).

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VALUE: Breezy

DEFINITION: Wind speeds 4 to 32 MPH (~3 to 37 knots); wind direction varies, but usually less than 180°.

CONDITIONS: At lower velocities, wind is evident, being felt on the face; leaves rustle and grasses move; a flag or cloth moves out a little from a staff. At higher velocities, large branches are in motion; whistling may be heard in any nearby wires; a flag or cloth stands straight from a staff and flutters vigorously. Wind directions may be constant, or more, up to 180°. Sampling is preferable at lower velocities. The support area should be upwind of the exclusion area. Ideally, wind should blow away from both the hazardous substance site and support area. A 40° arc of wind or less variation is the ideal, but 180° can be tolerated. A windshield should be in place. Changes in wind speed or direction should be noted during sampling. Higher wind speeds and variance in direction > 180° arc, may necessitate postponement of sampling. Check with local weather bureau for forecasts.

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VALUE: Calm to Light

DEFINITION: Wind speed < 4 mph (< 3 knots)

CONDITIONS: Smoke will rise vertically or drift with wind direction; flag or cloth on staff will lie limp or barely move. Variance in arc direction is relatively insignificant. The sampling condition is ideal. The wind shield is usually not necessary, unless winds become gusty and changing.

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## SECTION 4.0

### SOIL KNOWLEDGE FRAMES

This section contains soil knowledge frames that can be used in the field to identify and describe soils. The knowledge frames are presented in ESES documentation and derivatives such as this guide. The format of the knowledge frames is explained in Section 3.

This section presents soil knowledge frames for the following attributes:

- Bulk Density
- Cation Exchange Capacity (CEC)
- Clay Minerals
- Color
- Compaction
- Consistency
- Corrosivity (Corrosion Potential)
- Electrical Conductivity
- Fertility Potential
- Horizons
- Hydraulic Conductivity
- Infiltration and Percolation
- Mesofauna and Macrofauna
- Microbiota
- Moisture (Water) Conditions
- Odor
- Organic Matter and Litter
- Porosity
- Reaction (pH)
- Redox Potential (Eh)
- Roots
- Structure Grades
- Surface Features
- Temperature
- Temperature Regimes
- Texture Classes

## OBJECT/ATTRIBUTE: SOIL/BULK DENSITY

DEFINITION: The ratio of the mass of dry solids to the bulk volume of the soil (including air space) B.D. = g of soil dried (usually for 24 hr.) to 105° C/cc of soil volume obtained in the field.

VALUES: LOW  
MEDIUM  
HIGH

CATEGORY: SITE BACKGROUND

PROPERTIES: INPUT FACT

REFERENCES: American Society for Testing and Materials, 1984, Vol. 11.01  
Blake and Hartge, 1986, pp. 363-375  
Lewis, 1979, pp. 47-48  
Mason, 1983a  
Richards, 1954  
US EPA, 1991 a, Part II, Section 6, p. 12

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VALUE: Low

DEFINITION: The bulk density is usually between 1.0-1.3 g/cc of soil.

CONDITIONS: Bulk density is concerned with the soil solid particles and pore space. It is not an invariant quantity for a particular soil. Mineral soils usually have a bulk density greater than water 1 g/cc; organic soils may vary in bulk density from ~0.3-<1.0 g/cc of soil. Clay soils have the lowest bulk density except for some volcanic soils and highest related porosity. Soil bulk densities usually increase with depth due to less organic matter, less aggregation, and compression from the weight of the overlying soil. Lower bulk densities in association with good structure promote good aeration and drainage. Finer textured soils with higher organic matter than other mineral soils and more favorable structure have more pore space and lower bulk densities. Top soils in many areas have a value of 1 .1 -1.3 g/cc, Highly organic soils also will have a low bulk density both because the density of the solid material is low and there is a large amount of pore space. Bulk density will vary by soil horizons and layers and are considerably affected not only by texture and organic matter content, but also by its structure, compaction, puddling, swelling, and shrinking characteristics, which are dependent upon clay content and wetness. Soil metal adsorption and retention

can be greater in soils of lower bulk density. See related soil factors including knowledge frames on compaction, clay minerals, structure grades, texture classes and organic matter. Soil samples are procured in the field by the core or clod method. The core method is unsatisfactory for very hard, stony, or easily compacted soils. Radiation methods, using gamma transmission or scattering, may be used in the field to estimate bulk density, but it measures all combined components. See Boulding (1991) A Field Pocket Guide, for details.

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VALUE: Medium

DEFINITION: Soils generally with bulk densities between 1.3-1.6 g/cc of soil.

CONDITIONS: The bulk density values indicate soils of medium texture, usually clay loams, silt loams and loams, and significantly less organic matter than highly organic soils. For subsoils, bulk density values are usually greater than for those of topsoils and can range from 1.3-1.7 g/cc, but soil manipulation and other factors can also affect these values. Management or other practices that increase bulk density will also decrease the percent of pore space, restrict gas diffusion, reduce water movement and leaching. In general, metal retention and movement is affected as bulk density increases, when the texture becomes more coarse (sandy or loose), or the soil more compacted. These two factors work against each other and are complicated by other soil factors.

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VALUE: High

DEFINITIONS: Soils generally with bulk densities between 1.6-1.8 g/cc of soil.

CONDITIONS: The bulk density values indicate sands or sandy soils, or highly compacted soils with reduced pore space. Loose and coarse textured soils, such as gravelly loams may even exceed a bulk density value of 1.8 g/cc of soil as for medium bulk density values, any management practices that increases bulk density is usually unfavorable because it decreases pore space, restricts gas diffusion, and restricts water movement, especially for plant growth. A high bulk density indicated by coarse texture and loose materials favors movement and activity of metal ions; a high bulk density resulting from soil conditions such as compaction, reduces their activity, movement, and leachability. However, even in highly compacted soils, the bulk density may remain appreciably lower than the particle density, and the soil generally never becomes completely impervious.

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## OBJECT/ATTRIBUTE: SOIL/CATION EXCHANGE CAPACITY (CEC)

DEFINITION: The sum total of exchangeable cations that a soil can adsorb, expressed in milliequivalents per 100 grams or per gram of soil. Usually determined by ammonium acetate at pH 7.

VALUES: LOW  
MEDIUM  
HIGH

CATEGORY: SITE BACKGROUND

PROPERTIES: INPUT FACT

REFERENCES: American Society for Testing and Materials, 1984, Vol. 11.01  
Bache, 1979, pp.38-41  
Mason, 1983a  
Peck and Melsted, 1973  
Richards, 1954  
Rhoades, 1982a, pp. 149-157  
Talibudeen, 1981  
USDA Soil Conservation Service, 1984  
USDA Soil Conservation Service, 1970  
US EPA, 1991a, Part II, Sec. 7, 27 pp.

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VALUE: Low

DEFINITION: The CEC is < 12 meq/100 g soil.

CONDITIONS: CEC measures the ability of a soil to absorb (and release) cations, predominantly metals, but also ammonium, in exchangeable forms. It corresponds to the negative charge of soil. The predominant, naturally occurring exchangeable cations in soil are calcium, magnesium, potassium, sodium, aluminum, hydrogen, iron and manganese. In acid soils, calcium, magnesium, and aluminum predominate. In calcareous soils, calcium and magnesium occur at most of the exchange sites. The sodium ion predominates in salt-affected soils. All of the heavy metals in soil solution are primarily cationic except for molybdenum, which occurs as molybdate ion. The CEC generally increases as the pH rises, and with the increase in exchangeable sites provided by clays and organic matter content. Some kaolin mineral soils will have CEC of 1-8 meq./100 g of soil. The effective CEC of organic matter contributes approximately 2 meq./100 g of soil toward the



soil CEC. One percent clay provides approximately 0.5 meq./100 g soil. A low CEC is found in soils low in organic matter and clays as in sands and sandy loams, with approximately 2-12 meq./100 g soil. Mineralogical clay soils do not effectively vary in CEC when the pH is <5. Base-saturated soils, e.g., calcium, magnesium, potassium, sodium, and ammonium, are neutral in reaction, whereas nonbase saturated soils are acid. Iron, aluminum and titanium oxides, as well as noncrystalline iron and aluminum silicates and phosphates may add to the CEC of some soils. Addition of some chemicals, including those containing heavy metals, may additionally add to the soil CEC. With low CEC values, metal adsorption also is expected to be correspondingly low. Metal ions in soil water may be removed by adsorption and/or precipitation. Factors affecting the interrelationship between adsorption and precipitation are the concentration of the cations in the soil water, the cation-anion pairing, the complexation or chelation by organic molecules and soil pH. Changes in the soil solution and temperature will both cause a redistribution of ions between solution and exchange sites on clay minerals and oxides. CEC is not a soil property that is independent of the conditions under which it is measured, and it is seldom practical to determine the CEC of each soil sample relevant to its specific field condition. Different methods are to be used for arid land (and salty soils) or for acid soils. All values require procurement of a soil sample and subsequent analysis in the laboratory. Also see knowledge frame on Nature of Heavy Metal Soil Pollution, sections on CEC.

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VALUE: Medium

DEFINITION: The CEC is between 12-20 meq./100 g soil.

CONDITIONS: Soils that are loams or silt loams have representative CEC of approximately 12-20 meq. Naturally occurring cations (bases) along with certain contaminant metals will be retained by these soils, especially by clays, against rapid loss by leaching, but they may still be available for absorption by plants. Soils with more organic matter, along with a higher pH, also will tend to have a higher CEC than soils with less organic matter. Retention of cations, including mobile heavy metals, is higher for soils containing more clays, organic matter, and pH values above neutral.

VALUE:	High
DEFINITION:	The CEC is 20-40 meq. or more per 100 g soil.
CONDITIONS:	<p>The CEC is high in clay soils or those high in organic matter. Montmorillonitic clay soils will have higher CEC than kaolinic clay soils, up to 80-150 meq/100 g of soil. The CEC of illite is 10 to 40 meq/100 g of soil; kalonite, 3 to 15 meq/100 g of soil and oxides and hydroxides, 2 to 6 meq/100 g of soil. Organic matter has a CEC of 200 to 400 meq/100 g of soil. Cation selectivity in organic matter depends mainly on the disposition of the acidic groups. Cation selectivity also increases with CEC. There is a diminished contribution of organic matter to CEC at pH values &lt; 6.0. Depending upon the nature of the adsorbed cation or metal, the amount and nature of the adsorbent, and leachability, these soils will have a high ability to retain and/or release cations. If contaminated with applied chemicals, special attention should be given to these soils for adsorbed cations and their activity, either for their retention or susceptibility to be found in runoff or leachate.</p>

## OBJECT/ATTRIBUTE: SOIL/CLAY MINERALS

DEFINITION: Naturally occurring, inorganic, crystalline phyllosilicate (sheet layer silicate mineral) materials found in soils and other earthy deposits; not limited to particle size of 0.002 mm diameter or less.

VALUES: ABUNDANT  
MODERATE TO SLIGHT  
NONE TO NEGLIGIBLE

CATEGORY: SITE BACKGROUND

PROPERTIES: INPUT FACT

REFERENCES: Birkeland, 1984  
Cady, Wildung and Drees, 1986  
Dinauer, 1977  
Dixon and Weed, 1977  
Grim, 1953  
Kittrick, 1986  
Mason, 1983, pp. 5-14  
USDA Soil Conservation Service, 1970, pp. 39-42  
Stotzky, 1986

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VALUE: Abundant, > 27%

DEFINITION: Clay minerals are evident as a major constituent of the soil. Silicate clays are common in temperate zones; iron and aluminum hydrous (oxides and oxyhydroxides) clays are found in the tropics. Kaolinite (nonexpanding lattice structure) clays predominate in moist, warm climates; montmorillonite (expanding lattice structure) clays predominate in arid areas.

CONDITIONS: Clay minerals develop and are formed in soils through the weathering of parent rocks under conditions similar to those for soil forming factors: time, climate, topography, and effects of biota (vegetation). The same "type" of soil with a characteristic clay mineral composition can develop from rocks of widely different composition and texture after a relatively long period of time. Clay minerals exhibit physicochemical properties similar to those of plate- or sheet-like structure. Minerals with sheet-like structures can be categorized as kaolinites, illites, and montmorillonites. Because of their surface change nature, they have the ability to weakly adsorb cations from the soil solution. The weak chemical

bond has an important role in the overall chemical reaction of cations, organic content and hydrous oxides present in the soil.

An examination of soil properties in the field or laboratory reveals the effects and abundance of clay minerals. This examination of related soil properties should include texture, structure, porosity, infiltration, percolation, color, moisture-holding capacity and retention, consistency, compaction, and other properties. A nongritty soil with aggregates that, when wet, easily break down, and that is highly plastic reveals significant presence of clays. When dry, clay soils are extremely difficult to disaggregate. Clays are major constituents that influence the retention of water and chemicals and, under some circumstances, can control the rate of chemical (and ionic) migration through the soil. The more reactive the chemical, the greater its potential for being bound to the soil or changed by surface reaction with clay minerals. Laboratory clay mineralogical examinations should be performed, if necessary. A clay soil will have as much as or more than 10 times the exchange capacity that a sand does. Swelling and shrinking of clay soils may create macropores favoring preferential flow of water and liquid chemicals. This may limit the penetration of mobilized metals into soil peds. A compacted clay soil has increased bulk density and reduced pore space, and has the capacity to hold liquids and sorb metals. A saturated solution of malachite green in nitrobenzene may be used to detect montmorillonite and illite. A yellow-red color of wetted soil indicates montmorillonite; a purple-red color indicates illite.

Clay organic matter reactions and transformations are important. Bioactivity of pesticides, for example is related to the organic matter and to the clay minerals present. Cationic pesticides lose their bioactivity on contact with soil clay particles, become virtually immobilized, and resist biodegradation. Average CEC for clays is: montmorillonite, 100 meq/100 g of soil; illite, 30 meq/100 g of soil; and kaolinite, 8 meq/100 g of soil. The type and concentration of clay minerals affects the toxicity of heavy metals on microorganisms. The effect of clay minerals on the toxicity of heavy metals is usually an alternating effect and appears to be primarily a function of the CEC on clays. Cationic species of heavy metals have the ability to exchange for noncationic forms and thereby reduce the concentration of toxic metals in the soil solution.

Metal species may be tightly bound and difficult to dislodge from clayey soils, and their retention time is considerably longer than for nonclayey soils. Adsorption of heavy metals on clays can be considerably influenced by pH. For example, adsorption of cadmium, copper, lead and zinc to kaolinite, illite and montmorillonite increases as the pH increase, but if the pH is favorable for the formation of hydroxylated metal species, then the metal precipitates rather than be adsorbed. The background concentration of competing cations also affects

the adsorption of heavy metals to clay minerals as do also inorganic and organic ligands. When organic matter blocks the exchange sites on minerals, the selectivity for alkali metals, e.g., potassium, is considerably reduced. Formation of clay-organic-metal complexes reduces their susceptibility to microbial degradation, which can be important for bioremediation of some waste sites.

Presence of a large quantity of clay minerals may affect soil sampling procedures because of physical effects on soil properties and resultant difficulties in sampling when tightness or hardness makes the soil difficult to penetrate or dislodge. Also see knowledge frame on texture classes: clays.

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VALUE:	Moderate to Slight, 1 to 27%
DEFINITION:	Clay minerals are evident, but nonclays, including organics, also are significant soil constituents. A visual examination of soil particles may reveal a considerable percentage of visible single grains (> 50%).
CONDITIONS:	A small percentage of clay, even as low as 1 to 5%, will still have an influence on retention and exchange of water, other liquids, sorbed nutrients, and other soil properties. Contaminants, in general, are more free to move within the soil body than they are in a soil with higher clay content.

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VALUE:	None to Negligible, < 1%
DEFINITION:	Undetectable visual presence of clays and absence of effects of clays on other soil properties, as indicated under abundant value. Sands, silts, or organic matter are the predominant soil solids.
CONDITIONS:	Retention and exchange of water, nutrients, and chemicals, including metal species, are relatively insignificant. However, in natural soils important nonclay minerals may be present including carbonates, calcium-magnesium carbonate (dolomite), soluble salts of potassium and sodium (as chlorides, nitrates, and sulfates), partially soluble calcium sulfate (gypsum), and iron and manganese oxides, which have a high sorption capacity for heavy metals. Trivalent oxides of iron have extremely low solubilities in the normal pH range of soils. The geochemical nature and generally high specific surface area of iron oxides in soil particles and as coatings on other particles make them efficient sinks for anions such as phosphate, molybdate, and silicate as well as for heavy metals such as

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copper, lead, zinc, cobalt, chromium, and vanadium. Iron oxides also affect soil structure and matrix, often being responsible for the formation of aggregates and cementation of other major soil components. Manganese oxides also occur in soils as coatings on other soil particles, deposited in cracks and veins and as nodules. Manganese oxides also have high specific surface areas, carry a high negative charge in all but extremely acid soils, and have high adsorption capacities which can result in the accumulation of relatively high concentrations of heavy metals in soils. Manganese oxides are noted for their adsorption of lead and cobalt. Also see knowledge frame on soil texture: skeletal.

## OBJECT/ATTRIBUTE: SOIL/COLOR

DEFINITION: The phenomenon of light or visual perception of the soil's physical appearance in terms of hue, lightness, and saturation, measurement is by reference to standard color charts (e.g., Munsell color system for hue, value, and chroma) to make up a specific color notation.

VALUES: DARK  
RED AND YELLOW  
BROWN  
GRAY/WHITISH  
MOTTLED

CATEGORY: SITE BACKGROUND

PROPERTIES: INPUT FACT

REFERENCES: Munsell Color Company, 1954  
Olson, 1981, pp. 17-22  
USDA Soil Conservation Service, 1981, pp. 4-60 to 4-70  
USDA Soil Conservation Service, 1975, pp. 463-368  
USDA Soil Conservation Service, 1970, pp. 15-18

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VALUE: Dark

DEFINITION: A soil color usually related to significant organic matter content, unless dark-colored minerals are present.

CONDITIONS: Color and color patterns in soil are good indicators of drainage characteristics of soils, which is important contaminated sites. In general, dark or blackish soils, because of organic matter content are most productive and have good structure and other related favorable soil properties, but black soils can also be the result of minerals and poor drainage. Dark-colored soils low in organic matter may contain compounds of iron and humus, elemental carbon, compounds of manganese, magnetite and dark-colored clays. In well-drained soils, the color generally increases from light brown to black with increased organic matter. Also, note temperature effects on soil organic matter and color, and association of organic matter with colloids, compounds of iron and humus, manganese, and elemental carbon compounds. Highly organic soils will sorb higher concentrations of metal species and form metal-organic complexes which may increase mobility of metals under anaerobic conditions. See knowledge frame for

Soil Organic Matter. Use Munsell Soil Color charts for soil color designations of hue, value, and chroma (e.g., 2.5Y 2/0, a black soil).

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VALUE:	Brown
DEFINITION:	Brown soils contain significant amounts of iron oxide, organic matter, or both.
CONDITIONS:	These soils vary between dark and reddish to yellowish, with intermediate properties of both resulting from effects of soil-forming factors and development. Unless applied chemicals are highly colored, brown soils will be more affected in color by minerals, organic matter, and moisture content. A uniform brown color tends to indicate a soil that is well drained and not usually saturated with water. Metal species may be sorbed and complexed with organic matter or may interact with soil iron. Example of Munsell soil notation is 10 YR 5/3, brown.

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VALUE:	Red and Yellow
DEFINITION:	A red soil color is usually related to unhydrated iron ( $\text{Fe}_2\text{O}_3$ ); yellow, to hydrated iron ( $\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$ ).
CONDITIONS:	Uniform red and yellow soils are usually indications of good drainage and aeration (favorable porosity) and are seldom or never saturated with water. In general, they are considered less productive and are less fertile than black or dark brown soils. Iron oxides have a high pigmenting power and largely affect the soil color. The color of many reddish soils and yellowish-brown soils is due to iron oxides. Strongly red soils are expected to be highly permeable. Soil materials may be old, or have been subjected to a longer period of intense weathering. Red and yellow soils increase toward the equator. In deeper soils, a yellow color indicates a more humid effect on soil formation. Yellow soils may be due to hydrated iron oxides. Many yellow soils are imperfectly drained or from a previous condition of restricted drainage. Yellow soils have low inherent productivity. Red and yellow soils may indicate potential for more rapid movement of liquids than for dark-colored, organic soils, but drainage also may be impaired. Less metal species may be sorbed than in highly organic soils. Example of Munsell soil notation is 5R 5/6, red; 5Y 8/8, yellow.

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VALUE:	Gray/Whitish
DEFINITION:	Grayish or whitish soils are the result of several substances, mineral or organic.
CONDITIONS:	Whitish soils are indications of minerals such as quartz, kaolin, pumicite, diatomaceous earth, carbonate, or gypsum. Gray (or blue) colored soils indicate that the soil is saturated continuously or for extended periods and would retain contaminated solutes. Grayish colors (chroma <1) occur in permanently wet soils, in the presence of organic matter, may have low organic matter content or low iron, or with significant ferrous iron. Intense reduction (gleying) involves saturation of soil with water for long periods in the presence of organic matter. Gleyed soils change to brown upon exposure to air, with accompanying change in oxidation-reduction (Eh) status. Reduced forms of metals may be found in gleyed soils. Metals may become mobilized under anaerobic conditions. Unless applied pollutants are distinctly nongreyish or white, they may be obscured by the inherent soil colors. An example of Munsell soil notation is 2.5 Y 7/2, light gray.

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VALUE:	Mottled
DEFINITION:	A soil showing spots of different colors in a relatively uniform soil matrix.
CONDITIONS:	Colors of mottled soils are described by noting both the color of the predominant soil matrix and of the mottles. The dominant color (or colors) are given first, and then described as details of the color pattern. Description of mottles requires three sets of notation: contrast, abundance, and size. See the following table (Table 4-1) for describing contrast, abundance, and size, and Boulding, (1991), A Field Pocket Guide, for designation of mottle contrasts to be used with the Munsell Soil Color Chart.

TABLE 4-I. Terms for Describing Soil Mottles (Adapted from USDA SCS, 1981).

Distinctiveness	Contrast
Faint	Indistinct mottles. Closely related hues and chromas of matrix mottles.
Distinct	Mottles easily seen. Mottles vary from matrix as much as 1 or 2 hues or several units in chroma or value.
Prominent	Conspicuous mottles. Hue, value, and chroma may be several units apart.
<u>Abundance</u>	
Few	< 2% of exposed surface
Common	2-20% of the exposed surface
Many	> 20% of the exposed surface
<u>Size</u>	
Fine	< 5 mm in diameter
Medium	5-15 mm in diameter
Coarse	> 15 mm in diameter

Mottles have many different shapes in the soil matrix and these shapes should be noted if significant. Many mottles are roughly circular, but others are elongated or show merging streaks, tubes, bands, or spots. Soil mottles are affected not only by their chemical composition and oxidation state, but also by soil moisture conditions which may fluctuate. Reduced, wetter soils, or those found near a perched water table are lighter in color. Oxidizing conditions will have mottles of more distinct colors, e.g., dark reds and browns. As for soil color notations, mottles that are reddish or yellowish are more highly oxidized and weathered, whereas soils that are grayish whitish or bluish are more reduced or are in association with high or stagnant water tables. In humid regions, mottled soils with spots of different colors may have fluctuating water tables. Mottles in these soils may indicate seasonal conditions of wetness even if the soils are examined during drier seasons. Those mottled soils streaked with red, yellow, or black in a gray matrix are usually periodically saturated with water.

In addition to or in association with mottles, the soils should be examined for coatings or stains on the faces of or within aggregates. Crushed or rubbed aggregates may be examined for color characteristics. Mottles, stains, and coats can also indicate accumulations of metal contaminants and should be compared with the soil matrix in unaffected areas off-site. Close-up photographs and microphotographs may be useful to illustrate or describe these special soil

features by showing various color combinations in the soil matrix. Photographs may be especially useful if soil colors are pertinent to accumulations or concentrations of metal contaminants.

OBJECT/ATTRIBUTE: SOIL/COMPACTION

DEFINITION: The squeezing together of soil particles under mechanical load by rolling, tamping, or vibration to expel air; usually by the weight of farm, construction, and other equipment; vehicles; and animal and foot traffic.

VALUES: HIGH  
MODERATE  
LOW TO SLIGHT

CATEGORY: SITE BACKGROUND

PROPERTIES: INPUT FACT

REFERENCE: Bradford and Gupta, 1986.  
Hillel, 1982, pp. 176-199  
USDA Soil Conservation Service, 1970, pp. 45-47

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VALUE: High

DEFINITION: Surface soils have been subject to high compaction and consequent effects on soil structure, such as by vehicular and foot traffic or livestock.

CONDITIONS: Compaction of heavy, fine-textured, clayey soils reduces their porosity and capacity to hold moisture. For light, coarse-textured, sandy soils, compaction reduces porosity, but increases moisture-holding capacity. Aggregation is increased, along with bulk density. Infiltration rate of surface soils is decreased and runoff is increased. Disturbed soils are generally more subject to compaction than naturally occurring soils. Length of liquids standing on the surface is increased, and metal sorption to soil particles is increased. Compaction should not be confused with compression, which can result in a significant change (decrease) of either water or air in the soil pore spaces, a rearrangement of soil particles, compression and deformation of solid particles, and compression of the liquids and gases within the pore spaces. Some similar effects on soil metal particle sorption may occur whether the soil is compressed or compacted, except for changes in metal-moisture relationships.

VALUE: Moderate

DEFINITION: Surface soils have been less subject to compaction than highly compacted soils, either through reduced applications and frequency of pressure on surface soils, or because the soil structure is more resistant to compaction.

CONDITIONS: Soil porosity, moisture-holding capacity, aggregation, bulk density, infiltration, and runoff are less affected by compaction than in highly compacted soils. Movement of liquids is less affected, along with less activity and movement of metal species.

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VALUE: Low to Slight

DEFINITION: Surface soils have been only slightly affected by compaction, either because of resistance to compaction or because they are less subject to application of compacting stressors.

CONDITIONS: Surface soils show characteristics more similar to noncompacted or naturally occurring soils and will react similarly to applications of water and chemicals and to sorption of metal species. If the pore spaces are filled or nearly filled with water or other liquids, very little or no volume change will take place immediately upon the application of a load and very little or no air is expelled. If the water or other liquid can readily drain from highly permeable soil, the consolidation of the soil may take place within a short time period. If the permeability is low, then complete consolidation under an applied load may require several years. Usually, a low to slight compaction does not result in a significant change of water volume in the soil mass, and therefore has little effect on movement of mobile metal contaminants.

## OBJECT/ATTRIBUTE: SOIL/CONSISTENCY

DEFINITION: The resistance of the soil material to deformation or rupture; the degree of cohesion of the soil mass, and as described at various soil moisture contents,

VALUES: HIGH  
MODERATE  
LOW TO WEAK  
CEMENTED

CATEGORY: SITE BACKGROUND

PROPERTIES: INPUT FACT

REFERENCES: Mason, 1983b, pp. 5-3; 5-12 to 5-14;  
USDA Soil Conservation Service, 1981, pp. 4-81 to 4-84  
USDA Soil Conservation Service, 1975, pp. 475-477

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VALUE: High

DEFINITION: A soil when wet that shows high cohesion of soil particles, or adhesion of soil particles to other substances.

CONDITIONS: The reaction of soil when force is applied is closely related to the soil-water state, and reflects properties primarily of texture, organic matter, and cementing materials (e.g., salts), including certain chemical contaminants.

Clay soils tend to be sticky and plastic when wet; moderately to strongly smeary; fluid to very fluid; moderately firm, very firm to extremely firm. Review properties of texture, structure, clay minerals, compaction, porosity and soil moisture, particularly for clay soil characteristics. There is generally a lower potential for water and liquid chemicals to enter and migrate through a soil of high consistency, and with consequent retention of metal species.

Review conditions for determining soil cohesion/adhesion at specified moisture contents and values: plastic limit; water at maximum stickiness; smeariness at field capacity; fluidity under natural field conditions; and the interrelationships of consistency and soil structure.

VALUE: Moderate

DEFINITION: A soil when moist that shows moderate cohesion or adhesion.

CONDITIONS: The moist soil water condition (e.g., field capacity) reflects consistency related to properties of soils of intermediate texture and reduced amounts of clays and organic matter. Soils tend to be less sticky and plastic, less smeary, and less firm. In general, there is a favorable tendency for soil water and liquid chemical movement, with less potential for retention of metal species.

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VALUE: Low to Weak

DEFINITION: A soil, usually dry, that shows reduced or poor cohesion or adhesion.

CONDITIONS: The dry soil condition, as for a wet soil, most strongly reflects soil properties of texture, whether sand, silts, or clays, and varying degrees of organic matter. Dry clays and finer textured soils will be hard to very hard, nonplastic, firm to extremely firm, nonsticky, nonsmeary and nonfluid, varying in brittleness. Dry sands and coarse-textured soils lacking significant amounts of clays and organic matter will be loose or soft, friable, nonplastic, nonsticky, nonsmeary, and nonfluid, with strong potential to retain metal species.

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VALUE: Cemented

DEFINITION: A soil or horizon that remains hard or brittle after an air-dried specimen has been placed in water for at least one hour.

CONDITIONS: Cemented soils are evaluated both wet and dry. Cemented materials, after soaking for one hour, are weakly cemented, strongly cemented, or indurated (hard to extremely hard). Hardness and brittleness persist whether wet, moist, or dry. Soil particles are held together by cementing substances such as calcium carbonate, or the oxides of silicon, iron, and aluminum.

Cemented soils are not favorable for infiltration, penetration, and migration of water and liquid chemicals through the soil. Some applied chemicals may weaken cementation; compare with adjacent nonaffected soils. There is generally a high potential for retention of metal species, either as part of the cementing process, or independent of it. Sampling is unfavorable and may require vigorous mechanical procedures to break up the soil (e.g., jack hammer).

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## OBJECT/ATTRIBUTE: SOIL/CORROSIVITY (CORROSION POTENTIAL)

DEFINITION: The ability of the soil to wear away and degrade metal materials with time, usually by chemical and microbial action, and as determined by soil characteristics.

VALUES: HIGH  
MODERATE  
LOW

CATEGORY: SITE BACKGROUND

PROPERTIES: INPUT FACT

REFERENCES: Barttelli, 1962  
Olson, 1987, pp. 53-55  
USDA Soil Conservation Service, 1990  
US EPA, 1986b

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VALUE: High

DEFINITION: The potential ability or status of the soil to degrade metal materials to a high degree.

CONDITIONS: Corrosion is essentially a redox phenomenon, and much of it is largely bacterial in nature. The bacteria function as their own electrochemical cells to corrode metals. Soils with a high potential to degrade buried or partially buried metal materials are generally highly organic soils, peats and mucks, poorly drained, or highly alkaline mineral soils and water with a relatively high dissolved oxygen level. Corrosivity of metals in soils is promoted by finer textured soils, clays, or salty coarser textured soils, and those with a high or low pH, dark color, high or low oxidation-reduction potential (Eh), high aeration but also high moisture, high shrink and swell potential, cracking, and high amount of electrolytes in solution (as determined by electrical conductivity measurement). Corrosiveness of water tends to increase with decreasing pH. Conditions that favor the growth of microorganisms also will increase corrosivity, and the biodegradation of metal materials. The tendency of metal surfaces to oxidize is largely responsible for corrosion and subsequent heavy metal contamination of water. A high corrosivity potential is important for dissolution of metals, the increase in toxicity of a particular site, and availability for transport and spread of metal ions. Most rates of corrosion are normally slow.

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VALUE: Moderate

DEFINITION: Soils that have a medium potential for corrosion of buried or partially buried materials.

CONDITIONS: These soils tend to be less organic; of medium to coarse texture; exhibit less extreme pH; are moderately chemically reactive; less oxidative; exhibit less potential for cracking, shrinking, and swelling; and exhibit less influence of soil moisture and proximity of the water table. Electrical conductivity values of extracts are lower than for highly organic or for salty, alkaline soils. (See Soil Electrical Conductivity). Chemical reactivity and microbial biodegradation rates are slower, but movement of corrosive products may be greater in well-drained soils of medium to coarse texture.

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VALUE: Low

DEFINITION: Corrosion potential of buried or partially buried metal materials is discernibly less evident, or almost nil, over a relatively long period (several years to decades).

CONDITIONS: Loose, coarse-textured, dry, nonmoist and nonsalty, nonalkaline soils with low electrical conductivity will show low corrosion potential over an extended period. Microbial corrosion and chemical reactivity will be slow unless other soil conditions and foreign materials, such as wood and other organic products for energy and nutrition, are present and are in contact with metals. Transport of products of corrosion is reduced unless water is present and erosion forces are operative. Close proximity to water table or to irrigation can be accelerating factors for enhancement of corrosion and movement of erosion products, including corrosion of metal containers, dumped or spilled metal products, and leakage of liquids from corroded containers, both surface and subsurface.

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## OBJECT/ATTRIBUTE: SOIL/ELECTRICAL CONDUCTIVITY

DEFINITION:	The ratio of the electrical current density to the electric field in the soil; expressed in the reciprocal value of its resistivity in mhos/cm (or mmhos/cm) of soil extract or paste and generally referable to the salt/solute content of the soil or determined at a given moisture content and temperature. Note: The International System (SI Units) is siemens per meter, $\text{Sm}^{-1}$ . To convert mhos/cm to $\text{Sm}^{-1}$ , multiply by 0.1.
VALUES:	NONSALINE SLIGHTLY SALINE MODERATELY SALINE VERY SALINE EXTREMELY SALINE
CATEGORY:	SITE BACKGROUND
PROPERTIES:	INPUT FACT
REFERENCES:	Finkl, 1979a Rhodes and Oster, 1986 Richards, 1954

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VALUE:	Nonsaline
DEFINITION:	The conductivity of the saturation extract is < 2 mmhos/cm and the total salt content is estimated at < 0.1%.
CONDITIONS:	The electrical conductivity, total ionic concentration, and osmotic pressure of the soil solution (extracts) are positively correlated and can be related to important effects on natural vegetation, crops, and soils. For a nonsaline soil, the salinity effects for most plants and crops are negligible. For hazardous wastes, contaminant salts, if present, and unless from soluble toxic compounds, would not affect site vegetation or soil properties. Porous, well-drained soils would show little effect of any contaminant salts. Usually found in naturally occurring soils of humid regions.

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VALUE: Slightly Saline

DEFINITION: The conductivity of the saturation extract is 2 to 4 mmhos/cm, and the total salt content is estimated at 0.1 to 0.15%.

CONDITIONS: Sensitive vegetation and yields of very sensitive crops may be restricted. Compare suspected salt contamination with off-site vegetation.

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VALUE: Moderately Saline

DEFINITION: The conductivity of the saturation extract is 4 to 8 mmhos/cm, and the total salt content is estimated at 0.15 to 0.35%

CONDITIONS: Vegetation growth and yields of many crops are restricted. Compare any suspected salt contamination with off-site vegetation. Note sources of moisture, e.g., irrigation water, evidences of moisture retention, evaporation rates conducive to salt deposition and retention, and other soil properties conducive to salt accumulation, whether of natural or induced sources. Biodegradation of any accompanying organic contamination is impeded due to osmotic and other adverse salt effects. Some corrosive effects of salts may be evident, and interact with metal contaminants if moisture is sufficient.

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VALUE: Very Saline

DEFINITION: The conductivity of the saturation extract is 8 to 16 mmhos/cm, and the total salt content is 0.35 to 0.70%.

CONDITIONS: Vegetative growth is restricted, with sparsity of vegetation or evidence of halophytes. Only salt-tolerant crops will yield satisfactorily. Salt accumulation may be noticeable at the soil surface or within the soil profile. Biodegradation is inhibited. Corrosive effects of salts may be evident for metal materials, especially if moisture is sufficient. Arid land soils and irrigated soils in acidic regions may be affected.

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VALUE:	Extremely Saline
DEFINITION:	The conductivity of the saturation extract is > 16 mmhos/cm, and the total salt content is > 0.70%.
CONDITIONS:	Vegetative growth becomes more restrictive, or even absent in extreme situations of salt accumulation, with evidence of halophytes. Only a very few tolerant crops will yield satisfactorily because of the effects of excess soluble salts. Salts from contaminating sources exacerbate the situation for macro and microorganism growth and activity. Halotolerance will be evident, but biodegradation is generally very restricted. Corrosive effects of salts on metals can be particularly evident if there is sufficient moisture. Arid land soils and soils irrigated for a number of years may be affected. Nonsaline (alkali) sodic soils, high in exchangeable sodium, also should be noted for their adverse effects on vegetation and soil properties (e.g., structure), and interactions with metal species.

## OBJECT/ATTRIBUTE: SOIL/FERTILITY POTENTIAL

DEFINITION: The ability or status of the soil to supply nutrients necessary for plant growth, usually determined by soil tests (i.e., chemical, physical, or biological procedures that estimate a property of the soil pertinent to the suitability of the soil to support plant growth).

VALUES: HIGH  
MEDIUM  
LOW

CATEGORY: SITE BACKGROUND

PROPERTIES: INPUT FACT

REFERENCES: Barber, 1984  
Hendricks and Alexander, 1957  
Jones, 1979  
Plaster, 1985, pp. 171-192  
Sanchez, Conto, and Buol, 1982  
Soon, 1985  
Tisdale and Nelson, 1975, pp. 439-490

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VALUE: High

DEFINITION: The potential ability or status of the soil to readily supply nutrients necessary for plant growth.

CONDITIONS: Specific soil tests should be made to determine the nutrient status, both macro and micro nutrients of the soil. Tests may be performed for nitrogen, carbon, phosphorus, potassium, sulfur and others and for their availability for plant growth. General observations of the luxuriant nature and healthy condition of plant growth during the growing season are indicative of a fertile soil. In general, those characteristics indicative of high fertility are a favorable clay and organic (humus) content, a loamy texture, and good soil structure. Indicators of a highly fertile soil are warm, deep, moist soil with good drainage and tilth; less susceptibility or evidence of erosion; usually, a pH near neutral; favorable nutrient supply; and desirable microorganisms. A fertile soil generally has a greater capability to naturally recover from contamination, or to enhance remedial actions taken to reduce or clean up contamination. Interference of contaminant metals is not evident or effective, and potential for recovery from metal contamination may be more favorable than for soils with less fertility potential. (Fertility should not be

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confused with productivity. A productive soil has chemical, physical, and biological characteristics favorable for the economic production of crops suitable for a particular area.)

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VALUE: Moderate

DEFINITION: A soil with moderate potential or status to supply nutrients for plant growth.

CONDITIONS: Specific soil tests indicate the need for some additions of one or more nutrients to obtain optimal plant growth. In general, a moderately fertile soil shows less clay minerals and organic (humus) content, some structural aberrations, a less warm, moist, and moderate soil depth with some impeded drainage, increased evidence of erosion, less favorable tilth, a pH less favorable than neutral (too acid or too alkaline for most plants), a less favorable nutrient supply, and a reduction in the numbers and kinds of microorganisms relative to a highly fertile soil. The soil will respond to improvement in soil conditions, and plants will show some response to nutrient additions by increased absorption and growth characteristics. Moderately fertile soils generally will not recover as fast as highly fertile soils from contamination under natural conditions.

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VALUE: Low

DEFINITION: A soil with low potential or status to supply nutrients for plant growth.

CONDITIONS: These soils have an undesirably high clay or sand content and associated characteristics, and otherwise may show unfavorable physical characteristics of either extremely rapid or poor drainage, erosion and loss of top soil and organic matter, unfavorable manipulations resulting in compactions and reduced penetration and infiltration, poor tilth, shallow depth of soil, high degree of rock fragments and of nonsoil materials or debris, cold or excessively hot temperatures, a too dry or too wet condition, pH that is too acid or alkaline for most plants, a highly reduced or oxidized condition, inadequate or unfavorable microorganisms, and imbalanced or inadequate nutrient supply. Fertility of some soils may be improved by amelioration of soil physical characteristics and additions of nutrients to improve plant growth. Contamination of these soils may exacerbate already unfavorable conditions. Amelioration and cleanup may be difficult. Site usage and spread of contaminants, as well as other factors, will determine treatments and the necessity to enhance fertility status to promote plant growth, recovery of the site, and improvement of some soil properties.

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## OBJECT/ATTRIBUTE: SOIL/HORIZONS

DEFINITION:	A soil horizon is a layer of soil or soil material approximately parallel to the land surface and differing from adjacent genetically related layers in physical, chemical, and biological properties or characteristics such as color, structure, texture, consistency, kinds and numbers of organisms present, degree of acidity or alkalinity, etc.
VALUES:	MASTERS AND LAYERS TRANSITIONAL DISTURBED BURIED
CATEGORY:	SITE BACKGROUND
PROPERTIES:	INPUT FACT
REFERENCES:	Soil Science Society of America, 1987 USDA Soil Survey Staff, 1960, 1975, 1990, 1991

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VALUE:	Masters and Layers
DEFINITION:	Distinguishing master horizons and layers recognized in soil survey and represented by the capital letters O, A, E, B, C, and additional symbols of lower case letters and arabic numbers.
CONDITIONS:	<p>Soil horizons are described from the surface downward, and using the Master Horizon and Layer letter designations of O, A, B, C, and R. Further subdivisions use other number and symbols. The letter A is commonly used to designate the surface horizon or layer commonly known as topsoil. The letters B and C are used to describe subsoil horizons. The letter R describes hard bedrock.</p> <p>A basic description of master horizons and layers is given below. For further description and extensive details needed to classify soils, refer to the above references.</p> <p>An experienced scientist familiar with the particular area of concern should be contacted if possible, otherwise site documents, including local soil surveys should be consulted. Soil classification includes further grouping of horizons into series (approximately 10,000 in the United States), families, subgroups, great groups, suborders, and orders (10).</p>

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## MASTER HORIZONS AND LAYERS

**O horizons-** Layers dominated by organic material, except limnic layers that are organic.

**A horizons-** Mineral horizons that formed at the surface or below an O horizon and (i) are characterized by an accumulation of humified organic matter intimately mixed with the mineral fraction and not dominated by properties characteristic of E or B horizons; or (ii) have properties resulting from cultivation, pasturing, or similar kinds of disturbance.

**E horizons-** Mineral horizons in which the main feature is loss of silicate clay, iron, aluminum, or some combinations of these, leaving a concentration of sand and silt particles of quartz or other resistant materials.

**B horizons-** Horizons that formed below an A, E, or O horizon and are dominated by (i) carbonates, gypsum, or silica, alone or in combination; (ii) evidence of removal of carbonates; (iii) concentrations of sesquioxides; (iv) alterations that form silicate clay; (v) formation of granular, blocky, or prismatic structure; or (vi) combination of these.

**C horizons-** Horizons or layers, excluding hard bedrock, that are little affected by pedogenic processes and lack properties of O, A, E, or B horizons. Most are mineral layers, but limnic layers, whether organic or inorganic are included.

**R layers-** Hard bedrock including granite, basalt, quartzite and indurated limestone or sandstone that is sufficiently coherent to make hand digging impractical.

Important physical, mineral, chemical, and biological factors are characteristic of the various soil horizons within the pedon. These characteristics, in turn, as well as external environmental factors - soil forming factors - determine the development and extent of soil horizons. A diagnosis of soil horizons, therefore, yields important information relative to the soil, its nature and behavior. The characteristics of soil horizons are important to the movement, translocation, mobility and accumulation of various solutes and contaminants, such as the chemicals in wastes. An examination of the soil profile and its exposed horizons at toxic and hazardous waste sites should be compared with off-site analysis of horizons of the soil profile.



VALUE: Transitional

DEFINITION: A soil that possesses properties and distinguishing characteristics of two kinds of horizons, one superimposed on the other, or with parts characteristic of another.

CONDITIONS: There are two kinds of recognized horizons: (1) properties of an underlying or overlying horizon are superimposed on properties of the other horizon throughout the transition zone, and (2) parts that are characteristics of an overlying or underlying horizon are enclosed by parts that are characteristic of the other horizon. In soil survey, special conventions and symbols are used to designate these horizons. Usually eight transitional horizons are recognized. (See Keys to Soil Taxonomy by Soil Survey Staff, SMSS Tech. Monogr. No. 19, 1990 and other soil taxonomy references for details.) Transitional layers should be identified not only as part of the soil description, but insofar as they may affect changes in movement, translocation, reactivity, sorption, and accumulation of chemicals including metals in or from waste materials.

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VALUE: Disturbed

DEFINITION: Any soil that has been truncated or manipulated to the extent that its principle pedogenic characteristics have been severely altered or can no longer be recognized.

CONDITIONS: Disturbed soils may be found in nature due to environmental events such as tectonic events, floods, landslides, and erosional removal of distinguishing horizons.

Disturbed soils are a distinguishing characteristic of reclaimed mine lands, where soil is replaced as a material, and it has severely lost or suffered alteration of its original characteristics such as structure, porosity, permeability, organic matter, exchange capacity, pH-Eh, hydraulic conductivity and other moisture features, and various microbial, meso- and macro-biotic components, their activities and relationships. A new soil will develop in these areas, dependent upon soil forming factors.

Disturbed soils also may be characteristic of waste sites, especially if removed and subsequently replaced. Characteristics of the disturbed soil should then be compared with off-site soils occurring in the undisturbed or natural environment. Reactivity, fate, and transport of contaminants in the disturbed soil also may be compared with off-site soils.

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VALUE: Buried

DEFINITION: Soil covered by an alluvial, loessal, or other depositional surface mantle of new material usually to a depth greater than the thickness of the solum.

CONDITIONS: The surface mantle of new material is usually 50 cm or thicker. A mantle < 30 cm thick is not considered in taxonomy of buried soils. The surface mantle of new material is usually defined as unaltered. In the natural environment it is usually finely stratified and overlies a soil horizon sequence that can be clearly defined as the solum of a buried soil in at least part of the pedon. Wind and water deposits of soil, as well as landslides can result in buried soils in the natural environment.

Buried soils can also be identified at some excavated and filled areas, such as landfills and at waste sites where soil has been removed and replaced with trash or waste materials, and/or subsequently covered with a layer of excavated soil. Attention should be given to characterizing and describing the resultant overlaying soil materials and their development, and interaction with underlying materials, as well as effects on the buried soils, e.g., leaching and/or accumulation of chemicals from the overlying wastes. Buried soils also may be separated by liners of various areal extent, depth and composition and these may be checked for leaks into the surrounding soil.

OBJECT/ATTRIBUTE: SOIL/HYDRAULIC CONDUCTIVITY

DEFINITION: The rate of water movement within the soil; the proportionality factor in Darcy's Law as applied to the viscous flow of water in the soil, i.e., the flux of water per unit gradient of hydraulic potential.

Hydraulic Conductivity (K) Saturated - The ratio of the flux density to the hydraulic gradient, or the slope of the flux versus gradient curve in a water saturated medium (e.g., soil).

Hydraulic Conductivity (K) Unsaturated - The ratio of the flux density to the hydraulic gradient, or the slope of the flux versus gradient curve in an unsaturated medium (e.g., soil).

VALUES: HIGH  
MODERATE  
LOW  
IMPERVIOUS

CATEGORY: SITE BACKGROUND

PROPERTIES: INPUT FACT

REFERENCES: Amoozegar and Warrick, 1986  
Bouwer, 1979, pp. 99-102  
Brooks and Corey, 1964  
Green, Ahuja, and Chong, 1986  
Hillel, 1982, pp. 57-132  
Klute and Dirksen, 1986  
Lee, et al., 1985  
Mason, 1983b, pp. 5-21 to 5-23  
Reynolds and Elrick, 1986  
Reynolds, et al., 1985  
Talsma, 1960  
USDA Soil Conservation Service, 1981, pp. 4-35 to 4-37  
US EPA, 1986b

VALUE: High

DEFINITION:  $> 10 \mu\text{m/s}$  (.000001 meters/second).

CONDITIONS: Hydraulic conductivity is a complex phenomenon in soil. Hydraulic conductivity and hydraulic gradient are routinely obtained during hydrogeological investigations. For this reason, simple "theory" as well as a practical understanding of hydraulic conductivity are presented in this frame.

Transmission of liquids in the unsaturated (vadose) zone is critical in the design and monitoring of near-surface hazardous waste storage and disposal sites, land treatment facilities, irrigation and drainage systems, canals and reservoirs, tailings areas, septic tank systems and a number of other agricultural, industrial, and environmental installations.

Hydraulic conductivity (K) is the proportionality factor in Darcy's equation and relates the velocity (v) of water in a soil or other porous medium to the hydraulic gradient (i) as follows:  $v = Ki$ . The velocity is the gross velocity, or Darcy velocity as if the water (or chemical) were also moving through the solid particles of the medium (soil). The hydraulic gradient *i* is the rate of decrease in the total head (the sum of pressure head and elevation head) along a streamline in the direction of flow. It should be noted that the Darcy equation is not valid for all flow in porous media.

Hydraulic conductivity is universally proportional to the viscosity of the water, therefore, temperature should be specified for a certain K value. Both the hydraulic conductivity concept and Darcy's equations are based on laminar flow. Subsurface water flow is usually laminar although turbulent flow may occur in media with large pores and high hydraulic gradients. Flow in porous media is given in Reynolds numbers and is based on the Darcy velocity and the average particle size diameter. For most subsurface flow systems, the Reynolds Number is  $< 1$ , well below the range of turbulent flow.

Hydraulic conductivity, as a measure of the ease with which water moves through the soil is greatly dependent upon soil properties, particularly the sizes and configurations of the pores. Anything affecting the pore configuration will affect K, including entrapment of air in some of the pores, which will reduce the pore area available for water flow, and hence K is reduced. Because of air in pores, the K of unsaturated soil (vadose zone) is much lower than K at saturation.

The concentrations and composition of cations in the soil water determines whether or not the clay particles in the soil are flocculated or dispersed. These in turn determine the structure of the soil and hence also affect K.

Hydraulic conductivity, can be directional (anisotropy), and affected by groundwater, aquifers, basins, and soil horizons and layers. It can be given for the soil as a whole or for a particular layer or combination of layers. The layer with the lowest value determines the hydraulic conductivity classification for the soil.

Hydraulic conductivity is highly variable. Measured values for a particular soil series can vary by 100-fold or more. Values measured on soil samples taken only centimeters apart may vary by 10-fold or more. Furthermore, laboratory-determined values are generally higher than field-measured values, often by as much as 100-fold. Because of this variability, a single measured value is a poor indicator of a soil's hydraulic conductivity. An average of several values gives a reliable estimate that can be used to place the soil into a particular hydraulic conductivity class.

A distinction is made between saturated hydraulic conductivity and unsaturated hydraulic conductivity. Saturated flow occurs when soil water pressure is positive. It is the greatest rate at which water can move through the soil. In most soils, water pressure is possible when about 95 percent or more of the total pore space is filled with water. If the soil remains saturated for a long time (several months or more) the proportion of total pore space filled with water may approach 100 percent. Saturated hydraulic conductivity is a function of such soil properties as pore size distribution, pore geometry, total porosity (water-filled porosity at saturation), and clay mineralogy.

Three of the most important parameters governing liquid transmission include field-saturated hydraulic conductivity, sorptivity, and hydraulic conductivity which establish the pressure head relationship. Sorptivity is a measure of the capacity of a porous medium to absorb a wetting liquid; usually, the greater the sorptivity, the greater the volume of a wetting liquid that can be absorbed, and the more rapidly the liquid is absorbed. Sorptivity is dependent upon the pressure head. As the pressure head decreases, then the hydraulic conductivity decreases from the field-saturated hydraulic conductivity in an exponential fashion.

Unlike the saturated zone, soil pores in the unsaturated zone are not completely filled with liquid (water or chemicals). However, all unsaturated zone soil contains some measurable amount of water. Unsaturated zone soils generally do not accumulate water for any appreciable period of time, but they can hold large volumes of water at relatively high soil water matric potentials.

Water flow is unsaturated when the soil water is subject to a subatmospheric pressure. It is under a negative pressure potential. Unsaturated hydraulic conductivity is a function of the same soil properties as saturated hydraulic conductivity and also of the soil water content (water-filled porosity). Unsaturated

flow is always slower than saturated flow. The moving force is always greater at the wetting front zone, where water invades and advances into an originally relatively dry soil. The most important difference between unsaturated and saturated flow is probably in the hydraulic conductivity.

In the pressure head relationship for unsaturated flow, the change in hydraulic conductivity also decreases as the pressure head decreases; this decrease is in an exponential fashion, indicating that the pressure head relationship is hysteretic. Dependent upon the porous medium properties there will be different values depending upon whether the porous medium is wetting or draining and how long it has been wetting or draining before flow is reversed.

Solution of unsaturated flow problems usually requires predetermination of the soil hydraulic properties, namely, (i) the relationship between the capillary head,  $\psi$ , and the moisture content  $\phi$ , and (ii) the dependence of the hydraulic conductivity,  $K$ , upon the moisture content (sometimes their derivatives are applied as a matter of convenience). It would be desirable to determine all necessary data by direct measurements, but often this is impossible for one or more of the following reasons:

1. The measurements are costly and time-consuming.
2. The hydraulic properties of soils are of a hysteretical nature. Different relationships prevail for wetting and drying processes, and the actual relationships between  $K$ ,  $\psi$ , and  $\phi$ , depend upon the preceding history.
3. The soil variability is such that the amount of data required to represent the hydraulic properties accurately is enormous.
4. The values of hydraulic conductivity of some soils may vary by several orders of magnitude. Systems can not efficiently cover such a wide range.
5. The available experimental data can not represent the complete relationships describing the hydraulic properties.

Hydraulic conductivity does not describe the ability of soils in their natural setting to dispose of water internally. A soil may have a very high conductivity yet contain free water because there are restricting layers below the soil, or because the soil is in a depression where water from surrounding areas accumulates faster than it can pass through the soil. The water may actually move very slowly despite the soil's high conductivity. Actually, rate of water movement is a product of the hydraulic conductivity and the hydraulic gradient. Saturated hydraulic conductivity cannot be used to describe water movement under unsaturated conditions.

Soils that have high conductivity, such as gravels or deep sands, commonly transmit liquids downward so readily that the soil remains set for no more than a few hours after wetting. These soils have large connected pores. The layer of

soil or soil pedon has many continuous conducting pores that are usually medium to coarse. The size and continuity of pores are the critical factors. Many pores are large enough to be distinguished easily; their continuity and persistence when the soil is wet must be determined. Some medium- and fine-textured layers have strong granular structure and large connecting pores. Others have many large voids, pores, or root channels that transmit water rapidly. If the soil cracks when dry, the cracks may not close on wetting. Hydraulic conductivity of clean gravels can be 50-1000 m/day; natural sand and gravel mixes, 10-100 m/day; and coarse sand, 5-20 m/day. (See Table 4-31 for a comparison of hydraulic conductivity class limits in equivalent units). Metals and other contaminants in solution will move rapidly in soils with high hydraulic conductivity values. In general, there will be little absorptivity on soil particles.

Hydraulic conductivity classes in soil survey are defined in terms of vertical saturated hydraulic conductivity. Unsaturated hydraulic conductivity classes cannot be defined at this time. Since measured values of hydraulic conductivity are available on relatively few soils, estimates are based on soil properties and on correlations that have been made between properties and hydraulic conductivity measurements.

A number of field methods have been developed for in situ measurement of field-saturated hydraulic conductivity, sorptivity and the pressure head relationship, but few of these methods can measure all three parameters and many are not cost effective due to large equipment, personnel, time, and liquid refinements; however, the Guelph Permeameter is capable of simultaneous, in situ measurements.

TABLE 4-2. Saturated hydraulic conductivity class limits in equivalent units.

$\mu\text{m/s}$	$\text{m/s}$	$\text{cm/day}$	$\text{in/hr}$	$\text{cm/hr}$	$\text{kg s m}^{-3}$	$\text{m}^3 \text{ s kg}^{-3}$
100 =	$10^{-4}$	864.	14.17	36.0	$1.02 \times 10^{-2}$	$1.02 \times 10^{-8}$
10 =	$10^{-5}$	86.4	1.417	3.60	$1.02 \times 10^{-3}$	$1.02 \times 10^{-9}$
1 =	$10^{-6}$	8.64	0.1417	0.360	$1.02 \times 10^{-4}$	$1.02 \times 10^{-10}$
0.1 =	$10^{-7}$	0.864	0.01417	0.0360	$1.02 \times 10^{-5}$	$1.02 \times 10^{-11}$
0.01 =	$10^{-8}$	0.0864	0.001417	0.00360	$1.02 \times 10^{-6}$	$1.02 \times 10^{-12}$

VALUE:	Moderate
DEFINITION:	0.1 to 10 $\mu\text{m/s}$
CONDITIONS:	Soils commonly transmit water downward readily enough so that they remain wet for no more than a few days after thorough setting. Layers may be massive, granular, blocky, prismatic, or weakly platy if they contain common continuous pores. If the soil cracks when dry, the cracks may not close on setting. This class includes many soils considered favorable for rooting and for supplying water to plants. Medium sands will have a hydraulic conductivity of 2-5 m/day; fine sands, 1-2 m/day; and, loams, 0.1-1 m/day. Solutes and contaminants will not be transported as readily as in coarse soils with higher conductivity values, thereby increasing their retention time in the soil pore-water system, and delaying their movement into water bodies such as ground water or large aquifers.

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VALUE:	Low
DEFINITION:	0.01 to 0.1 $\mu\text{m/s}$
CONDITIONS:	<p>Soils commonly transmit water downward so slowly that they remain wet for a week or more after thorough wetting. Soils in the low class are structureless or have only fine and discontinuous pores (as in some clays, fragipans, or cemented layers). Layers may be massive, blocky, or platy. Structural plates or blocks commonly are overlapping. There are few connecting pores that could conduct water when the soil is wet. If the soil cracks when dry, the cracks close completely on wetting. Plant roots are usually few or absent and are localized along the cracks. Slickensides and continuous stress surfaces also indicate low hydraulic conductivity.</p> <p>In dense or structured clays, the water moves through the very fine pores between clay particles. Sandy clays, silts, and some loams, mixture of sands, silts, and clay may be included in this class. A certain threshold gradient may be necessary to initiate water movement through such fine pores. Because the surfaces of clay particles are negatively charged, they will absorb cations. Considerable concentrations of cations, including metal contaminant ions may, therefore, concentrate in these soils with very fine pores and become absorbed on soil particles. The hydraulic conductivity is <math>&lt; 0.1</math> m/day and approaching zero in dispersed clays.</p>

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VALUE: Inhibited

DEFINITION:  $< 0.01 \mu \text{ m/s}$

CONDITIONS: The hydraulic conductivity class indicates practically impenetrable and impermeable soil conditions either because of homogenous clays, which may be satiated, the soils are naturally hydrophobic, or hydrophobic through the addition of waste substances. Water and applied chemicals remain on the surface for very long periods, or depend upon certain environmental circumstances, such as runoff for removal. Metal contaminant retention in solution may be high; comparisons should be made between on-site and off-site areas.

OBJECT/ATTRIBUTE: SITE/SOIL INFILTRATION AND PERCOLATION

DEFINITION: Infiltration (penetration): The downward entry (penetration) of water into the soil through the soil surface.

Percolation: The downward movement of water through the soil.

VALUES: HIGH  
MEDIUM  
LOW  
INHIBITED

CATEGORY: SITE BACKGROUND

PROPERTIES: INPUT FACT

REFERENCE: Bouwer, 1982  
Hill, 1979  
Hillel, 1982  
Morel-Seytoux, 1979  
Musgrave and Holtan, 1964, pp. 12-1 to 12-30

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VALUE: High

DEFINITION: Infiltration and percolation rates > 5 cm/hr. (> 2 in/hr)

CONDITIONS: In nature, infiltration and percolation are seldom uniform, either because of surface features, texture, structure, porosity, initial degree or state of wetness, etc. As water penetrates the soil, its distribution in space and time varies. For a given soil, depending on its permeability and capillary characteristics, the infiltration capacity will vary according to whether or not the soil was initially dry or already fairly wet when water or a liquid chemical is added. Soil structure will determine the direction of water movement. Prismatic and columnar structure enhance vertical percolation; blocky and granular structure enhance percolation both vertically and horizontally. Biological effects on infiltration can include growth of microorganisms on the soil surface. Algae, lichens, bacteria, fungi and also mosses can affect infiltration by their accumulation of biomass, metabolic products, entrapment of gases and binding with soil particles. Determination of infiltration rate is important to predicting surface runoff (and therefore streamflow), the movement of solutes and mobilized metals through the soil profile.

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In loose sands, the infiltration and rate of movement in a uniform profile can be expected to exceed 20 mm/hr. However, soil crustiness, such as from raindrops, windblown materials, etc. may initially impede infiltration, and discontinuities, e.g., weak pans, may alter uniform progress of percolation and wetting zone. As an example, in one typical situation, upon encountering a coarse (sandy layer of higher saturated hydraulic conductivity overlying a less conductive finer-textured (loamy or clay) layer, the infiltration rate is at first controlled by the coarse layer, but when the wetting front reaches and penetrates into the finer-textured layer, the infiltration rate can be expected to drop and tend to that solely of the finer-textured soil. In the opposite situation, with a fine-textured layer over a coarse-textured one, infiltration is again determined by the upper layer. However, as water reaches in interface with the coarse lower layer, infiltration may decrease.

In normal, as well as contaminated soils, nutrients and/or ions penetrate and percolate through the soil profile, and are usually impeded or slowed by differences of soil horizons and discontinuities in many soil profiles. In sites disturbed by the addition of toxic or hazardous wastes, dissolved contaminants may infiltrate and percolate into and through the soil at an expected rate determined by uniformity of soil properties, but where horizons and discontinuities are evident, variations in concentrations of contaminants may also occur.

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VALUE: Medium

DEFINITION: Infiltration and percolation rates 1.5 to 5 cm/hr. (0.6 to 2.0 in/hr)

CONDITIONS: In sandy and silty soils, rates commonly vary from 10 to 20 mm/hr. In loams, rates vary from 5 to 10 mm/hr. Variations in these rates for natural occurring, undisturbed soils may be attributed to surface and subsurface horizons and conditions, irregularities and discontinuities as described above. In toxic or hazardous waste sites, soil conditions may have been altered and the expected infiltration and percolation rates may not occur. Such deviations from expected values should be compared with off-site determinations and an analysis made for contaminants.

VALUE:	Low
DEFINITION:	Infiltration and percolation rates 0.15 to 1.5 cm/hr. (0.06 to 0.6 in/hr)
CONDITIONS:	Low or restricted infiltration rates are typical of clayey soils or those with claypans or other restrictive pans, severe compaction of finer soil materials, severely reduced porosity, and other alteration of the soil surface or profile to limit infiltration and penetration of liquids. Platey structures restrict vertical percolation. In agriculture, puddled soils, commonly clays, are manipulated, dense, massive and artificially compacted when wet and can have severely reduced infiltration and percolation rates. Clayey soils are not conducive for penetration and movement of either water or applied chemicals. Surface and shallow accumulations of contaminants may be evident at hazardous waste sites having clayey soils. See soil texture classes, clays.

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VALUE:	Inhibited
DEFINITION:	< 0.15 cm/hr (0.06 in/hr)
CONDITIONS:	<p>There is very slow or no water or liquid chemical movement into or through soil. Internal soil properties or external environmental factors greatly restrict the movement of liquids applied to the soil surface or through the soil. Sodic clayey soils exhibit this property. Repellency can be observed in naturally occurring soils due to climate (temperature) surface or subsurface hardness, or cracking, aggregation, compaction and formation of dense surface crusts and exposed surface pans with restricted porosity, occlusions due to detachment and migration of pore-blocking particles, or from the swelling of clay, from the entrapment of air bubbles or bulk compression of soil air. Soils of deforested and cultivated tropical regions, and some desert soils with caliche and other hardened salts may show inhibited infiltration of percolation.</p> <p>In toxic or hazardous waste sites, the prior application, infiltration and percolation of liquid chemicals may have so altered the soil surface and structure that liquids can no longer penetrate the soil surface or move through the soil. In special cases, ponding over the soil surface and the submergence of the soil, has so altered the soil surface, or the subsurface soil is so saturated that percolation can no longer be measured. Under conditions of initial shallow ponding, infiltrability and percolation may vary and decrease with time, depending on the initial wetness and water potential factors of the soil. Ponds over soil at toxic or hazardous waste sites also should be sampled for contaminants.</p>

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OBJECT/ATTRIBUTE: SOIL/MESOFAUNA AND MACROFAUNA

DEFINITION: Soil Mesofauna - Soil-inhabiting animals smaller than soil microbiota (microorganisms), including nematodes, small oligochaete worms (Enchytraeids), small insect larvae, and the microarthropods; of the latter, the soil mites (Acarina), springtails (Collembola) are often the most abundant permanent soil inhabitants.

Soil Macrofauna - Soil-inhabiting biota that generally include the larger insects, earthworms (Lumbricidae) and other organisms which can be easily sorted by hand; and commonly include burrowing vertebrates, such as moles, ground squirrels, and pocket gophers, which affect soil structure.

VALUES: MANY  
COMMON  
FEW  
NONE

CATEGORY: SITE BACKGROUND

PROPERTIES: INPUT FACT

REFERENCES: Borror and White, 1970  
Cloudsley-Thompson, 1988  
Eisenbeis and Wichard, 1987  
Kevan, 1962  
Kevan and Hill, 1979  
Kuehnelt, 1961  
Ricklefs, 1979  
Schaller, 1968  
Wallwork, 1970, 1976  
Woolley, 1982

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VALUE: Many

DEFINITION: Mesofauna > 100,000 to > 10,000,000/m<sup>2</sup>;  
Macrofauna > 5/m<sup>2</sup> to 10/m<sup>2</sup> of soil.

CONDITIONS: Many kinds and activities of mesobiota and macrobiota, primarily soil animals, will have a significant effect on the soil. (Small and large animals not associated with the soil, e.g., foxes, deer or cattle, are not included as soil macrofauna, but should be noted and described if present). These effects include modifications

of soil structure and consequent effects on infiltration and penetration of liquids, increase in number and kinds of pores, increase in aeration and permeability, hydraulic conductivity, water retention or movement, aggregation, increase in organic matter decomposition and other soil factors. Soil runoff and/or erosion also may be influenced by the number and activities if the surface soil is greatly disturbed or loosened. Animals to note include mites, ants, millipedes, cicada larvae, beetles, grubs, earthworms, sowbugs, slugs, snails, and small mammals: mice, moles, prairie dogs, gophers, shrews, woodchucks, squirrels, and rabbits; reptiles: snakes, lizards and tortoises. Ground-nesting birds also may be included.

Soil macrobiota can be readily seen with the naked eye. Soil macrofauna commonly include earthworms, larger molluscs, slugs, snails, and larger arthropods that can be measure in cm. Larger soil mesofauna can generally be seen with the naked eye, are >100  $\mu\text{m}$  long, (although many nematodes are microscopic), and include many of the enchytraeid worms and the smaller molluscs and smaller arthropods. Small mesobiotic forms are seen mostly near the surface of the soil, or in the "A" horizon (see soil horizons). More than 80 percent of all known soil animal species are arthropods - the most diverse of soil inhabitants. The most abundant soil arthropods are mites (arachnida and acarina) and springtails (collembola). The larger soil animals are sometimes described as "megafauna," because they utilize the soil primarily as a habitat and not as an energy source or for other soil biota interactions.

Many soils will have a large diversity and abundance of mesofauna, especially in highly vegetated areas or where soils have favorable systems of pH-Eh, nutrients, organic matter, porosity, and structure, etc. Translocation of materials is oftentimes promoted from one soil horizon to another by the burrowing of soil animals. Their holes or borrows form open channels which carry air, water, nutrients as well as contaminants into the deeper layers. Complex networks may be formed which are capable of impounding great quantities of water, solutes and contaminants.

Irregular tubar streaks, known as Krotovinas, may appear within one soil horizon consisting of soil materials transported from another horizon, and caused by the filling of tunnels made by burrowing animals, effects of soil animals on the soil system, their numbers, kinds and diversity should be compared with analyses and observations of uncontaminated off-site areas and with various soil contaminants.

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VALUE: Common

DEFINITION: Mesofauna > 100 to approximately 100,000/m<sup>2</sup> of soil;  
Macrofauna approximately 5/m<sup>2</sup> to 10/m<sup>2</sup> of soil.

CONDITIONS: Less abundant, less diverse, and lesser volume, but still showing significant influences on soil properties, and on the mixing and changing of soil materials with less effects on the overall soil system. Soils of forests, grasslands and semi-arid areas will show greater abundance and diversity than arid areas. Compare effects on soil animals, their numbers, kinds and diversity with uncontaminated off-site areas, and the observations and analysis of various contaminants.

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VALUE: Few

DEFINITION: Mesofauna > 10 to approximately 100/m<sup>2</sup> of soil;  
Macrofauna 1 to 5/m<sup>2</sup> to 10/m<sup>2</sup> of soil.

CONDITIONS: A very low number of mesofauna and only a few macrofauna can be detected. The natural environment is itself restrictive, e.g., lack of available moisture, limited available nutrients, limited organic matter, restrictive temperature and temperature regime, compaction, or other soil and site characteristics, such as found in desert or compacted soils. Contaminating wastes may be present in what otherwise may seem to be "normal" soils and should be compared with uncontaminated off-site areas and analyses for various contaminants.

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VALUE: None or only an occasional meso or macrofauna detected per specified unit of surface area, 1/m<sup>2</sup> to 10/m<sup>2</sup>.

CONDITIONS: The natural environment is extremely adverse for meso and macrofauna and generally lacking in vegetation and/or limiting soil properties, e.g., extremely barren and isolated deserts, or toxic and hazardous wastes which have greatly affected the soil environment to eliminate or prohibit the habitation and activities of meso and macrofauna. Megafauna, as well as small and large animals, are also probably lacking in these sites, except as transients. For recently added contaminants, dead, or dying animals, including birds, (or aquatic biota in transient or permanent ponds), may be evident. Definite comparisons should be made with uncontaminated off-site areas and analyses made for non-observable contaminants.

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OBJECT/ATTRIBUTE: SOIL/MICROBIOTA

DEFINITION: Generally, microscopic forms, such as soil algae, especially green and blue green types and diatoms, autotrophic and heterotrophic bacteria, fungi, actinomycetes, streptomycetes, myxomycetes and protozoa.

VALUES: ABUNDANT  
COMMON  
FEW  
NONE

CATEGORY: SITE BACKGROUND

PROPERTIES: INPUT FACT

REFERENCES: Alexander, 1973, 1971                      Parkinson and Paul, 1982  
Atlas, 1986, 1988                                  Paul and Clark, 1989  
Burns, 1986    Schaller, 1968  
Clark, 1957, 1979                                  Schmidt and Paul, 1982  
Grell, 1973    Shields, 1982  
Hattori, 1979                                        Shtina and Hollerbach, 1979  
Huang and Schnitzer, 1986                      Silver, et al., 1986  
Jacobs et al., 1957                                Stotzky, 1986  
Kaspar and Tiedje, 1982                        Tabatabai, 1982  
Kevan and Hill, 1979                            Wallwork, 1970, 1976  
Knowles, 1982                                      Wollum, 1982  
Kuehnelt, 1961                                    Woolley, 1982

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VALUE: Abundant

DEFINITION: A large diversity of kinds and/or number of viable metabolic groups of microorganisms, ranging from 1,000,000 to > 10,000,000, microorganisms/g of soil.

CONDITIONS: Microorganisms can solubilize and oxidize a number of waste constituents. Microbes not lethally affected by the waste product may decompose both the toxic and nontoxic compounds, particularly organics, into products that can be metabolized further. Metals can be oxidized or reduced by at least one type of soil microorganism which may be present at the site, and depending on the availability or lack of free oxygen and other substances in their habitat.



The microbial population within the disposal site depends upon waste composition, concentration of toxic material, nutrients available, oxygen levels, temperature, pH, Eh, moisture content and availability, the initial population found in the waste liquid or solids, and any admixes such as soil. Aerobic microorganisms may be succeeded by microaerophiles or facultatives, followed by anaerobic species, as oxygen is depleted. Anaerobic microorganisms may then predominate to generate significant amounts of gases such as methane, hydrogen sulfide, and ammonia that can cause both odor problems and potential explosion hazards. Microbial activity may change substantially over time and may become more significant as a disposal site ages. The numbers and/or kinds of microorganisms are large, and usually indicative of a normal and “healthy” soil system. Depending on the “type” of soil, its depth and conditions, large numbers of algae, bacteria, fungi, actinomycetes, streptomycetes, and protozoa may be found along with numbers and kinds of aerobes, microaerophiles, facultatives and anaerobes; various metabolizers, heterotrophes and autotrophes, etc.

Nematodes are sometimes considered with the microbiota, but generally live outside of soil macrostructure and obtain great length, and therefore can be included with the mesofauna. Because of their agricultural significance, nematodes are often considered separately under Phylum Nematoda. Rotifers, small turbellarians and tardigrades also may be observed. Rotifers and turbellarians, as both aquatic and soil-inhabiting species, may be very sensitive to pollution.

Myxomycetes (slime molds), plasmodial or uncellular, and sometimes considered intermediate between fungi and protozoa, should not be overlooked in soils rich in organic matter, including dung. They can spread extensively over the surface layers of moist, highly organic soils where they feed on other microorganisms and help maintain a soil population balance. They may be inhibited by contaminants, including organics, which can interfere with their activities, including formation of typical fruiting structures.

Viruses may be included with soil microbiota, although they are submicroscopic in size. They can parasitize the other microbiota; organic residues, humus, and clay have considerable potential to absorb viruses. Presence, absence or variations in viral activities may be indicative of presence of pollutants.

Soil (and rock) lichens vary in size from microscopic to macroscopic forms. They are usually not included with the soil microflora. Soil algae and algal crusts may be attacked by fungi to form lichens. They grow slowly and are important in soil stabilization, some can fix atmospheric nitrogen and they can be indicators of pollution, including acid precipitation and radioactive fallout. Formation and development of soil lichens can be an indication of longer term soil stability. Comparisons should be made on- and off-site.

Mycorrhiza are not soil microorganisms in a strict sense, being an association of fungus hyphae (mold-like threads) in association with the roots of green plants to form modified root structures. Many trees show this modified root structure of closely woven masses of fungal hyphae, especially in the surface layers of soil and decaying litter. Mycorrhizae can have considerable influence on uptake of inorganic nutrients, including uptake of essential macro and micronutrients. Mycorrhizal formation may be particularly pronounced in soils low in phosphorus and nitrogen. Uptake of metals, when levels are relatively low, is enhanced by mycorrhizae, but increased uptake has also been found at toxic levels, leading to decreased tolerance and reduced growth of the host plant. The extent, nature and development (or absence) of mycorrhizae in contaminated sites may be compared with off-site areas of similar soils and vegetation.

Allchthonous microbiota - those not indigenous to the soil - may enter the soil system in precipitation, manure, sewage, diseased tissues, wastes, etc. They may persist for some time, but do not contribute in a significant way to ecologically important transformations or interactions in the soil for an extended period. Make comparisons with indigenous species on- and off-site.

Lacking diversity of microorganisms, soil conditions may be temporarily limiting, or because of some inhibition imposed by the presence of wastes. A large number of a few species of a single taxon, e.g., cyanobacteria, may be indicative of a selective substrate and/or conditions imposed by the waste materials or substance(s) and should be carefully investigated, particularly as waste indicators. Some cyanobacteria, for example, live on sewage and oil wastes and can tolerate some radioactive wastes. Some other bacteria utilize metals, e.g., iron, as energy sources. Although such microorganisms can serve as indicators, increasing attention is being given to endemic or site-specific microorganisms for bioremediation purposes, including various materials and substances in toxic, hazardous, and radioactive waste sites.

It should be noted that considerable care should be taken to sample, handle, store and enumerate soil microorganisms. Use of aseptic techniques to avoid introduced contaminants, and therefore bias of samples, is extremely important, along with handling and storage in both field and laboratory. Enumeration by various techniques, e.g., enzymes, DNA probes, various microscopic techniques, e.g., direct count, or culture techniques, e.g., plate cultures on selective and elective media, including soil extracts and dilution techniques, can be used to estimate and determine the numbers and kinds of microorganisms. Samples may be taken from soil horizons, various soil structures and locations suspected of contamination; and, comparisons made with samples taken from similar uncontaminated off-site areas.

VALUE: Common

DEFINITION: A diversity and/or number of viable microorganisms can be detected, ranging from > 10,000 to 1,000,000 microorganisms/g of soil.

CONDITIONS: A diversity of kinds of microorganisms may include those in various phyla or an abundance of one or more species. Diversity may indicate more normal conditions limited only by soil factors such as temperature, moisture, nutrients, aeration, and pH-Eh, etc. or low inhibition of wastes. A restricted diversity may indicate more limiting factors in the soil system and if wastes are present, then the effects of toxics should not be precluded. One or a few species and metabolizers of a single phylum may be highly indicative of toxic effects. Such microorganisms may be cultured and retained for further study, including possible site remediation.

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VALUE: Few

DEFINITION: < 100 to 10,000 total viable microorganisms/g of soil.

CONDITIONS: Numbers, kinds, and diversity of microorganisms is greatly reduced and may be restricted to favorable or selective microhabitats, usually where moisture, nutrients, ionic interactions, and pore relationships are conducive to growth and reproduction. Only a few populations or species of microorganisms may be present and they may be unevenly distributed. Depending on the availability of oxygen, aerobic, microaerophilic, or anaerobic metabolisms may prevail. Unit size of aggregates and fine microstructure (< 0.01 mm) may greatly inhibit or restrict microorganisms. Microfauna generally live outside the units of microstructure. Most algae and fungi live mainly outside the units of fine microstructure. Only bacteria, and many actinomycetes and some streptomycetes, can live within the units of fine microstructure; however, large matrixed colonies and mats of soil cyanobacteria (blue green algae) also may be limited, because of size or habitat outside the units of fine microstructure and to the surface or top few cm soil where light is available. Hazardous and toxic wastes, especially liquid chemicals may greatly limit the abundance of populations, diversity, and species of a number of microorganisms, or else restrict them to more favorable microhabitats within the soil system. Growth, development, inhibition or toxic effects may be determined on specific culture media, including that derived from waste materials. Compositing of samples may not accurately indicate the numbers of microorganisms in favorable and select microhabitats. Compare with microorganisms in similar soils, if possible, in off-site environments.

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VALUE:	None
DEFINITION:	None or only an occasional viable microorganism of any kind can be detected/gm soil.
CONDITIONS:	Some sites, both natural and disturbed, may not contain any detectable, or only occasional survivable microorganisms. In the natural environment, conditions may prevail which preclude or prohibit growth, or survivability. These can include physical and chemical conditions, e.g., volcanic sites, isolated, extremely cold, or dry, sandy or salty deserts. In some waste sites, lack of a suitable substrate, ionic imbalance, and inhibitory conditions, e.g., toxicity from recalcitrant molecules or materials may prohibit survival and/or growth and reproduction of microorganisms for any significant time. Allochthonous microorganisms or transients may survive temporarily; nonasepsis of sampling tools, procurement, and containers, etc. may account for some microorganisms not otherwise endemic to the site.

OBJECT/ATTRIBUTE: SITE/SOIL MOISTURE (WATER) CONDITIONS

DEFINITION: The degree or extent to which a soil holds moisture and is affected by its moisture potential and content, either long or short term.

VALUES: WET  
MOIST  
DRY

CATEGORY: SITE BACKGROUND

PROPERTIES: INPUT FACT

REFERENCES: Bruce and Luxmore, 1986, pp. 663-686  
DeHaan and Bolt, 1979  
Gardner, 1986, pp. 493-544  
Gupte and Larson, 1979  
Hillel, 1982, pp. 57-132  
Klute, 1986a, pp. 635-662  
Richards and Richards, 1957  
USDA Soil Conservation Service, 1981, pp. 4-27 to 4-29  
Wagenet, 1986, pp. 1055-1088

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VALUE: Wet

DEFINITION: A soil at time of sampling with obviously discernible moisture content as determined by sight and touch, with a high degree of adhesion or cohesion, and resistance to deformation or rupture. See soil consistency: high.

CONDITIONS: An increased amount of water in surface particles greatly decreases their detachment and transport by wind, but breaks down soil aggregates. If the surface layer consists of water-stable and chemical-stable aggregates, water and chemicals drain rapidly, but if aggregates are not stable, then large pores disintegrate, and pore size is narrowed, thereby decreasing mobility of ions. In completely saturated soils, all the voids are filled with water or liquid chemicals and promote concentration of solutes. In general, the concentration of the metals in the soil solution is of increased concern, along with their total concentration, although the total amounts of the individual heavy metals in solution are usually very low. There may be little movement of heavy metals into drainage water following continuing applications of raw sewage containing metals. The heavy metal contents of sludges depend, to a large extent, on the nature of the local industry and on the proportions of industrial and domestic

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wastes. The contents of individual sludges are highly variable, but ranges of metals are similar. Zinc is almost always present in the highest amount, followed by copper, although depending on the local industry, lead, chromium or nickel may exceed copper. Postpone soil sampling if soil is too wet, not only because of sampling difficulties, but also because of increased potential for sampling and analytical bias during sample handling, transport, and storage. Wet soil generally cannot be sieved, except with considerable difficulty and expenditure of time. Usually, soils are air-dried before sieving for most soil analyses. Sample bias also may be introduced if an attempt is made to sieve wet samples. Also see knowledge frames on hydraulic conductivity and redox potential.

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**VALUE:** Moist

**DEFINITION:** A soil at time of sampling with some discernible moisture that is slightly or moderately wet, with a moderate degree of adhesion or cohesion, and moderate to slight resistance to deformation or rupture. See soil consistency: moderate.

**CONDITIONS:** A moist surface soil is less conducive to hydraulic erosive influences than a wet soil, with an increase in soil aggregate formation. Infiltration and penetration by water and chemicals are promoted, along with drainage and movement through pore spaces. See knowledge frame on infiltration and percolation.

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**VALUE:** Dry

**DEFINITION:** A dry surface soil at time of sampling lacks discernible moisture, either through surface evaporation or percolation to lower depths of the soil profile. The degree of aggregate formation is low, with a low degree of adhesion or cohesion, and with a high degree of resistance to deformation or rupture, except as modified by texture and structure. See soil consistency: low to weak.

**CONDITIONS:** Depending on soil texture and structure, a dry soil, unless protected by vegetation, is more subject to erosive influences of wind and water, especially to strong winds and sudden, strong, downpours or flooding. Infiltration and penetration by water and chemicals are more likely affected by the soil surface conditions than wet or moist soils, and whether the soil is crusty and hard, or loose and friable. Crust formation is a result of previous wetting and will affect penetration and transport of applied water and chemicals. Metals sorbed to soil particles, both inorganic and organic, are of greater concern, because soil pores are filled with air, rather than liquids, but leaching potential is a possibility. Mobility of lead is low, regardless of soil moisture status. See knowledge frame

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on nature of heavy metal soil pollutants and section for specific metal or metalloid.

## OBJECT/ATTRIBUTE: SOIL/ODOR

DEFINITION: The quality or character of the smell of the soil, especially when dislodged for olfactory examination.

VALUES: HIGH  
MODERATE TO SLIGHT  
NONE

CATEGORY: SITE BACKGROUND

PROPERTIES: INPUT FACT

REFERENCES: Hazco, 1987, pp. 4.1.1 to 4.1.3.9 and 4.2.1 to 4.2.19  
Mason, 1983b, p. 5-14  
McKee and Wolf, 1963, pp. 228-229  
US EPA, 1979, 140. 1-1 to 140.1-7

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VALUE: High

DEFINITION: A distinct odor, whether of naturally occurring soil organic materials with a distinctive, pungent, musty odor, or sharp distinct odor from chemical contaminants.

CONDITIONS: Naturally occurring soils high in organic matter will have pungent musty odors, even more so if they are mucks or peats, but also including forest and grassland soils. Odors of naturally occurring, undisturbed soils should be compared with soils that are chemically contaminated for any suspected and recognizable chemical odors. Stains and discolorations should be noted. In contaminated soils, organics such as hydrocarbons are a major source of odor, especially neutral fractions, having low threshold concentrations. Aging causes petroleum odors to become musty. Gasoline may give a strong odor for some time. Among the chemicals responsible for odors, especially noticeable in the soil solution, are halogens, sulfides, ammonia, turpentine, phenols and cresols, picrates, various hydrocarbons, unsaturated organic pesticides, and many others.

Except for cyanide, contaminants in the CLP "heavy metal" category may not be evident, but may be suspect if organic contaminants are detected. Soils that are highly contaminated with organic chemicals, especially volatiles, should be examined carefully with regard to odors, and possible resultant personnel health effects. Sampling of noticeably artificially odorous soil should proceed with caution, and with careful examination of contaminated materials for sources of

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odors within the soil profile. It may be necessary for the site safety officer to make a decision about the level of protection needed for sampling personnel. CAUTION: Do not vigorously inhale odors from any soil. Even naturally occurring soils may harbor disease-producing microorganisms; inhalation of a large quantity of otherwise harmless microorganisms can be detrimental.

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VALUE: Moderate to Slight

DEFINITION: A less distinct to faint odor whether from naturally occurring soil organic materials, or from various odor-producing chemical contaminants.

CONDITIONS: All of the same conditions and characteristics of highly odoriferous soils are applicable to soils having strong or distinct odors, but to a lesser degree. Comparisons should be made within the site for variations in odors, and correlations with various kinds and concentrations of contaminants. Precautions still should be used in testing the soil for odors, especially contamination on the soil surface as well as within the soil profile.

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VALUE: None

DEFINITION: No detectable odors by olfactory means, but not to the preclusion of odors detectable by instrumental field analysis.

CONDITIONS: Visual evidence of surface or subsurface contributions to odor are absent. Organic matter, whether naturally occurring or induced, is generally lacking or nil. Volatile organics, if previously present, have evaporated or moved into the vadose zone or ground water. Instrumental field analysis may be performed, such as with a photoionization detector, if more detailed analyses are desired. Contaminating metal species may or may not be present,

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**OBJECT/ATTRIBUTE: SOIL/ORGANIC MATTER AND LITTER**

**DEFINITION:** Organic matter: material of plant or animal origin that decays in the soil to form humus. Litter: the surface additions of freshly fallen leaves, twigs, stems, flowers, fruits, and bark.

**VALUES:** ABUNDANT  
MODERATE  
SPARSE

**CATEGORY:** SITE BACKGROUND

**PROPERTIES:** INPUT FACT

**REFERENCES:** Armson, 1979, pp. 63-85  
Finkl, 1979b  
Manahan, 1972  
Morrill, et al., 1982  
Nelson and Sommers, 1982, pp. 539-579  
Schnitzer, 1982, pp. 581-594  
Shaw, 1989  
Soil Science Society America, 1987

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**VALUE:** Abundant, > 4%

**DEFINITION:** Soil and surface organic matter primarily of plant remains in concentrations > 4% of total mineral soil, up to 80% (mucks). Organic soils such as peats, mucks, bogs, and tundra; forest soils; and some rich grasslands.

Surface litter: the surface layer, usually in forests, of freshly fallen leaves, twigs, stems, flowers, fruits, and black soil.

Organic matter: the indigenous organic component of the soil system, both living and dead, partially or highly decomposed. Roots and microorganisms constitute a high proportion of the living fraction.

Humus: the total organic compounds in soil, exclusive of undecayed, partially decomposed or biomass materials.

**CONDITIONS:** A large amount of litter and soil organic matter can be observed in dark-colored soils and can retain a large number of chemicals, forming organometallic compounds. These soils will have a high water-holding and chemical-holding

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capacity, increased friability, and water-stable and chemical-stable structure. Organic matter may be an important sorbent of hazardous compounds. It is more easily eroded than most mineral compounds and tends to remain in suspension because of its low densities. As much as 65 to 75% of the organic matter in mineral soils may consist of humic materials with very large surface areas (500 to 800 m<sup>2</sup>/g) and high cation exchange capacities. Humus, because of its large surface area, associated surface properties and functional groups, can serve as a buffer, and a chelating agent, as well as a general sorbent, all of which are important in the attenuation of hazardous compounds in soils. Most of the organic matter in soils is comprised of humic substances.

Humic substances constitute the most important class of complexing agents that occur naturally in soils. Complexing or chelation of metal ions by humic substances, both soluble and insoluble, is one of its most important qualities in a metal-organic environment. Iron and aluminum are very strongly bound to humic substances. Other ions, such as divalent nickel, lead, zinc and calcium are intermediate in their binding to humic substances. Magnesium is rather weakly bound. Insoluble humic substances, the humins and humic acids, are effective in ion exchange and exchange of organic materials with water and may accumulate large quantities of metals. The more soluble fraction of humus, fulvic acid, dissolves in water and exerts its effects in water solution. Fulvic acid-type compounds may be responsible for keeping transition-metal ions in solution. Amino acids constitute another class of naturally occurring complexing agents formed from the breakdown of proteins. They can form very stable complexes with some metal ions, but binding power is less than for humic substances. At pH < 6.0 amino groups bind more strongly to cation exchange sites in a mineral matrix.

The interaction between heavy metals and humic substances has been characterized as chelation, complexation, and adsorption, as well as many other terms. Regardless of the term used or the type of chemical bond, heavy metals have a very strong affinity for organic matter in general, and humic acids in particular. Humic substances have a selectivity for the alkali metal cations. Although a variety of results have been obtained, a generalized listing of metal-humic substance stability constants is given as follows for some metals (divalent forms):

lead > copper > nickel > cobalt > zinc > cadmium > iron > manganese

Stability constants vary with many factors including pH, Eh and the method used for stability constant determination.

Estimates of heavy metal retention times vary considerably. Lead has one of the longer retention times of any heavy metal and even here the variability in

estimates varies considerably. An estimated mean residence time for forest floors can be 150 to 500 years. Complexation has a strong effect on the equilibrium of lead. When lead is oxidized, it is strongly bound to the product ion, thus reducing its solubility considerably. Upon oxidation many metals form self-protecting coatings of carbonates, oxides or other insoluble species, which inhibit further chemical reaction. However, a chelating agent in contact with such metals can result in dissolution of the protective coating, thereby increasing corrosion and dissolution of metals. Retention times in soils for copper and zinc are much shorter than for lead regardless of fairly similar heavy metal-organic matter stability constants. This is considered to be an effect on preferential uptake by vegetation.

The organic matter serves as a liquid reservoir for fixed and exchangeable metal ions. Addition of fluids can promote downward translocation of metals in soil as soluble complexes of organic matter.

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VALUE: Moderate, 2 to 4%

DEFINITION: Amounts of organic matter of 2 to 4% (or more) are representative of mineral soils, such as are found in some grassland soils and soils with scattered vegetation and their remains. Surface soil is usually discernibly colored by presence of organic matter as compared to lower horizons.

CONDITIONS: Surface organic materials are sufficient to affect physical conditions of soils, and with lesser capacity than for highly organic soils. Organic-clay complexes are important in sorption and fixation of metals. The amount of organic matter is still important in retention and release of water and chemicals.

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VALUE: Sparse, < 2%

DEFINITION: Amounts of soil organic matter are c 2% or even negligible, as in some highly mineralized, arid land soils, or disturbed soils subjected to turnover or removal of naturally occurring surface soils. Dark-colored organic matter may be too disorganized or too small to be visually recognized.

CONDITIONS: Soil properties such as texture, structure, aggregation, consistency, porosity, moisture-holding capacity, color and other soil factors are relatively unaffected by the organic content (especially > 1%) being overridden by effects of soil minerals, particularly clays, if present.

## OBJECT/ATTRIBUTE: SOIL/POROSITY

DEFINITION: The volume percentage of the total bulk of soil not occupied by solid particles.

VALUES: COARSE  
MEDIUM  
FINE  
VERY FINE

CATEGORY: SITE BACKGROUND

PROPERTIES: INPUT FACT

REFERENCES: Finkl, 1979c  
Hillel, 1982, pp. 135-151  
Marshall and Holmes, 1979, pp. 194-199  
USDA Soil Conservation Service, 1981, pp. 4-84 to 4-85

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VALUE: Coarse

DEFINITION: Pores > 5 mm in diameter.

CONDITIONS: Interconnected macropores provide free movement of water and chemical liquids. General nature of large pores should be compared with descriptions of surface features, texture, structure, organic matter, moisture content, hydraulics, consistency, root and animal activities (burrows) and other properties that are routinely described. Note any unusual arrangement of voids that facilitate movement of liquids: their shape, configuration, and orientation. Pores > 10 mm in diameter may be described separately, and if so, then their number and proportion of cross section and occupancy should be recorded. In addition to pore size, pores also are described by their quantity and size. The movement of water and chemicals is generally rapid through pores of large size but also depends upon the shape and arrangement of pores and other soil physical factors. The ability of the soil to retain water and chemicals is reduced and the degree of leaching is increased.

Quantity classes of pores are defined by the numbers of each kind and size per unit area -- 1 cm<sup>2</sup> for very fine and fine pores and 1 dm<sup>2</sup> for medium and coarse pores. See Boulding, (1991), A Field Pocket Guide, for charts illustrating an estimation of pore size. All pores smaller than 10 mm in diameter are described by the following quantity classes:

Few: Less than 1 per unit area of the specified size

Common: 1 to 5 per unit area of the specified size

Many: More than 5 per unit area of the specified size

Pores > 10 mm in diameter may be described separately. If described separately they are counted, and the number and proportion of the cross section they occupy is recorded.

Most described pores will be either vesicular (approximately spherical or elliptical), or tubular (approximately cylindrical and elongated). Some are irregularly shaped and can be described simply as "irregular" or, if significant, any other shape can be recorded.

Pores are assumed to be within the pad (ii a soil has pads) unless otherwise noted.

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VALUE: Medium

DEFINITION: Pores 2 to 5 mm in diameter.

CONDITIONS: Interconnected, 2-mm to 5mm pores still provide relatively free movement of liquids. Many pores, compared to fewer macropores, will provide for significant movement of liquid contaminants and for contaminants carried in liquids, but movement is also dependent upon shape, configuration, and orientation as for larger sized pores. Chemical properties, such as pH, Eh, and fertility will have more of an effect than they will for soils that have larger pores.

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VALUE: Fine

DEFINITION: Pores 0.5 to 2 mm in diameter.

CONDITIONS: Finer pores will reduce infiltration, penetration, and percolation rate of water and liquid chemicals, but still allow for significant rate of entry of water and less viscous chemicals unless soil is frozen or otherwise compacted and impeded. Movement within the soil body of liquid chemical contaminants is reduced or impeded. Determine associated soil properties that may restrict or affect flow rates, e.g. texture, structure consistency, compaction, and structure.

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VALUE: Very Fine

DEFINITION: Pores < 0.5 mm diameter.

CONDITIONS: Movement of water and chemical liquids is lessened, unless a few larger pores are present and other soil features do not interfere with movement of liquids (e.g., fine-textured clay soils), and effects of poor structure. Chemical as well as other physical soil properties will have a considerable effect on a noticeable slow movement of liquid contaminants.

Pores smaller than 0.075 mm in diameter are micro pores and may be described separately, though this is rarely practical in fieldwork.

## OBJECT/ATTRIBUTE: SOIL/REACTION (pH)

DEFINITION: The degree of acidity or alkalinity of a soil, usually expressed as a pH value, and ranging from extremely acid (< pH 4.5) through very strongly alkaline (pH > 9.1). Soil pH is the negative logarithm of the hydrogen ion activity, usually of a soil solution or paste.

VALUES: ACID  
NEUTRAL  
ALKALINE

CATEGORY: SITE BACKGROUND

PROPERTIES: INPUT FACT

REFERENCES: ASTM, 1988d, G51-77, pp. 910-911.  
Bache, 1979  
Coleman and Mehlich, 1957  
Richards, 1954, pp. 17-18  
USDA Soil Conservation Service, 1983, pp. 603-90 to 603-92

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VALUE: Acid

DEFINITION: An acidic soil (solution) has a pH value < 6.6 to 7.0 (neutral), with acidity increasing logarithmically with decrease in pH; extremely acid at < pH 3.5 to 4.5.

CONDITIONS: Soil pH, along with Eh, can have a significant effect on solubility and chemical and microbial reactions occurring at a waste site. In general, pH affects solubility by alteration of simple solution equilibria, and by direct participation in redox reactions. The soil pH can be greatly affected by the type of waste disposal. Hazardous wastes can contribute to pH change due to their own specific characteristics or by the dissolution of waste materials into the soil liquid fraction. The Soil Survey Staff (1991) defines a number of gradients of soil pH, defining 13 pH classes.

Acidic soils usually are not < pH 4.0; ultra acid is < 3.5. They are found in increasingly humid regions. Acidic reactions are closely correlated with factors of soil formation, development, and composition. In strongly mineral acid soils, especially < pH 5.2, the dominant cation (positively charged ion) is trivalent aluminum, unless an acid clay, which also contains hydrogen ions. Very acid or peat soils or those with organic acids will contain relatively more free hydrogen ions. In general, application of heavy metals to acid soils will increase their solubility, exchangeability on soil particles, and hence, mobility and leachability into

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the soil solution and movement through the soil profile. Corrodible materials will show an increasing degree and rate of corrosion in increasingly acid soils. Follow standard procedures and precautions for colorimetric or potentiometric (pH meter) determinations of soil pH in the field; refer to information on soil properties (e.g., exchange phenomena) for details and interpretation.

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VALUE: Neutral

DEFINITION: A surface soil (solution) of pH value -7.0 (6.6 to 7.3); a base saturated soil, as compared to an acid soil.

CONDITIONS: Neutral soils generally have favorable reaction properties, with approximately equal numbers of cations and anions (negatively charged ions) on or near the soil particle surfaces. Amounts and kinds of finely divided mineral and organic particles are favorable for soil reactions, including some favoring sorption, fixation, exchange, and release of metal ions. A pH > 6.0 (but < 7.5) is favorable for most cropping systems. Note that pH measured in the field may not be the same as in the laboratory, because of effects of carbon dioxide and need for equilibration with the atmosphere, however, because of buffer effects, the value may be similar. A carbon dioxide content of -2% is common in many soils, resulting in a pH of -7.1, but this is also dependent on other soil factors such as organic matter and porosity.

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VALUE: Alkaline

DEFINITION: A soil (solution) > 7.0 (commonly defined as 7.3 to > 9.1). Strongly alkaline > 9.0.

CONDITIONS: Alkaline soils, and some saline soils are more often found in arid climatic regions with high evapotranspiration rates and potential for poor water quality due to dissolved salts. An alkali soil is a salty soil that contains sufficient sodium to interfere with plant growth; a saline soil is a nonalkaline salty soil with less exchangeable sodium, but with sufficient soluble salts (e.g., carbonates) to interfere with growth of most crop plants; pH is usually < 8.5. The soluble cations and anions commonly found in saline and alkali soils are calcium, magnesium, sodium, potassium, carbonate, bicarbonate, sulfate, and chloride.

The addition of chemical liquids to relatively unleached soils of alkaline pH values may lower their pH if their solutions are acidic, but will exacerbate the pH of saline and alkali soils if alkaline. At high pH values metals are strongly adsorbed, largely because the surface charge of manganese and iron oxides increases with increasing pH. To maintain maximum adsorption in a soil or waste disposed

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system both a high pH and Eh should be maintained. The higher pH of alkaline soils tends to retard metal solubilization. Although arid zone climatic and soil properties may limit movement of applied liquids, other properties will increase potential for release and movement (e.g., sudden rainfall, flooding, runoff, and erosion by water and wind).

A large change in soil pH will result in a radical modification of the soil environment. Compounds normally held in the soil may precipitate out; others normally insoluble may dissolve. Note any differences in pH and effects at the site with that of the surrounding environment. Consult literature on pH and ion exchange phenomena and on characteristics of contaminants before undertaking sampling if effects of pH are significant due to applied chemicals (e.g., use special sampling tools, techniques, and containers, if necessary).

## OBJECT/ATTRIBUTE: SOIL/REDOX POTENTIAL (Eh)

DEFINITION: The potential that is generated between an oxidation or reduction half-reaction and the hydrogen electrode in the standard state.

VALUE: HIGHLY OXIDIZED  
INTERMEDIATE  
HIGHLY REDUCED

CATEGORY: SITE BACKGROUND

PROPERTIES: INPUT FACT

REFERENCE: Baas Becking, et.al., 1960  
Barlett, 1981  
Blanchar and Marshall, 1981  
Hesse, 1971  
Merkle, 1955  
Ralston, 1979

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VALUE: Highly Oxidized

DEFINITION: The soil system is highly oxidized, approaching values of +700 millivolts (mv).

CONDITIONS: Through oxidation-reduction reactions metal ions in aqueous solution can obtain stability. Acid-base reactions, precipitation and complexation use other means. Many of the most important redox reactions are catalyzed by microorganisms.

Soil Eh may vary with other factors such as water content, organic matter, oxygen activity in the soil and pH. Oxidation - reduction processes influence contaminant behavior in soils as much as any biological or chemical factor oxidizing conditions tend to favor attention of contaminants as opposed to reducing conditions. Oxidizing conditions are usually associated with higher pH values than reducing conditions. Also see knowledge frames on soil reaction, soil microbiota and organic matter.

The higher the Eh value, the greater the oxidizing intensity of the soil system. Well-aerated soils range from +700 to +400 mv. Soil conditions are generally highly aerobic, dry, or have the pores filled with fresh water, are low in organic matter content, possess oxidized elements and ions, and high oxides. Soil "types" are typically found in arid and semi-arid areas, are well drained and are not compacted

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or tightly layered. The corresponding pH levels are usually high as for alkaline soils.

Hydrous oxides of iron, manganese and aluminum, along with organic matter, have an important part in the oxidation - reduction processes in soil. Significant concentrations of iron and manganese oxides may further poise the system toward a high oxidation state, but organic matter and waterlogging may moderate a high oxidation state. Iron is relatively easily oxidized to ferric ions. An excess of oxidized manganese may completely immobilize iron to the ferric state, in which conditions it is easily precipitated.

Very highly oxidized soils may occur at waste sites subjected to contamination with materials having high oxidizing capacity and intensity and further denoted by a high pH and/or corrosive properties, e.g., caustic materials such as sodium and potassium hydroxide, halogenated solutions, strong brines of common salt (sodium chloride), and other industrial or processing solutions. With sufficient oxygen present and nontoxicity of wastes, aerobic microbial activity should prevail.

Soil Eh measurements are not as well poised as pH measurements and results may not be as concordant as for soil pH. For safety reasons, great care should be taken in regard to sampling and handling highly oxidized, contaminated soils. Precautions also should be taken in regard to field sampling, tools, containers, instruments, etc., and especially electrodes used to measure redox potentials.

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VALUE: Intermediate

DEFINITION: The soil system is moderately oxidized or moderately reduced, ranging from approximately +400 to -100 mv.

CONDITIONS: The values of Eh will depend considerably on available oxygen and other oxidized compounds. With sufficient (or abundant) oxygen, transition metals - iron, manganese and copper - are present in the soil as oxidized compounds of very low solubility. Unless there are sufficient poisoning substances, significant additions of materials can alter the Eh (as well as pH) of the system. Different soil horizons also may have naturally different states of oxidation or reduction, e.g., an oxidized upper red soil, a lower depth yellow soil, blending into reduced grays, slate-blues and blacks. Such horizons also may be altered by the addition of chemical contaminants, and show a change in Eh and/or pH.

Most plants flourish best in a moderately oxidized soil. Oxidized forms of nutrients constitute the principal nutrient sources; reduced products, even though present in low concentrations, are toxic to most cultivated plants.

Most microorganisms occur as aerobes, facultatives or microaerophiles in a moderately oxidized or reduced system. Certain populations of microorganisms can be found in milieus defined by limits of pH-Eh in the natural environment and will be affected as this milieu changes or shifts with the addition of poise - threatening contaminants. Soil pH-Eh milieu also can provide important information regarding the potential fixation of an element or contaminant in the soil.

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VALUE:                Highly Reduced

DEFINITION:        The soil system is highly reduced, with values of -100 to -300 mv or greater.

CONDITIONS:        Soil conditions are generally anaerobic, with high concentrations of organic matter, presence of reduced elements and ions, and are waterlogged, or with stagnant water. Soil "types" are generally found where mucks, bogs, and peats occur, as well as where soils are permanently submerged, under water of varying depths and which include bottom deposits and permanent swamps (the water may be fresh or salt); the soils are periodically waterlogged by submergence; soils are affected with a high and fluctuating water table (and sometimes partially aerobic), e.g., paddies. Microorganisms can initiate acute reducing conditions when aeration is poor and there is an abundant supply of oxidizable materials, such as nitrogenous wastes, green plant residues, and certain readily biodegradable, non- or low-toxic materials.

Reducing conditions favor accelerated migration of heavy metals as opposed to oxidizing conditions. For example, contaminants such as arsenic, beryllium, chromium, copper, iron, nickel, selenium, vanadium and zinc are much more mobile under anaerobic than aerobic soil conditions.

Manganese ions are readily reduced to soluble manganous ions and may be leached from the soil. As the reducing environment becomes more intense, ferrous iron precipitates as gray-green ferroferric hydroxide. Manganese also becomes solubilized to manganous ions and may be leached from the soil or more commonly, translocated to sites where it is precipitated. The ubiquitousness of manganese influences iron mobility as well as other heavy metals, and similar to iron, manganese oxides clog soil pores, inhibiting the downward flow and percolation of water.

The reduction of iron in soils is biologically dominated. The reduction process is most prominent at low pH values, and under anaerobic conditions when organic matter is abundant, especially as humus. The presence of sulfate and accompanying sulfate-reducing bacteria also favors iron reduction. Gleying of soils becomes more prominent as soils are reduced, and reduced horizons may appear;

a great majority of soil horizons subject to strong reduction are uniformly gray in color.

If the water table fluctuates appreciably, but the profile remains saturated most of the time, the deeper horizons will have gray backgrounds spotted or streaked with yellowish brown, and give rise to commonly spherical iron or iron-manganese concretions. Water logging, such as may occur below landfills, favors accelerated mobility of most metal solutes unless hydrogen sulfide is produced which unites with metals to form insoluble precipitates.

Chemical wastes, including mine wastes, added to reduced soil systems, e.g., acid sulfate soils such as in the tropics or marshlands, may exacerbate the system if they are strongly acid and corrosive. Acid sulfate soils respond poorly to improvement of drainage. Sludges, manures, and buried vegetation also generally exacerbate a reduced state of the soil system.

## OBJECT/ATTRIBUTE: SOIL/ROOTS

DEFINITION: Usually, the underground parts of seed plant bodies that function as organs of absorption, aeration, and food storage or as a means of anchorage and support, and differ from stems, especially in lacking nodes, buds, and leaves.

VALUES: MANY  
COMMON  
FEW  
NONE

CATEGORY: SITE BACKGROUND

PROPERTIES: INPUT FACT

REFERENCES: Harley, 1979  
Miller, 1974  
Stern, 1988  
USDA Soil Conservation Service, 1981, pp. 4-94 to 4-88.  
Weier, et. al., 1982

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VALUE: Many

DEFINITION:  $> 5/\text{cm}^2$  for fine and very fine roots;  $> 5/\text{dm}^2$  for medium and coarse roots.

CONDITIONS: Quantity, size, and location of roots in the soil should be recorded along with their relationships to other soil properties, e.g., soil structure, aggregations, porosity, horizons, and whether inside or outside of peds. In terms of size classes, roots vary from very fine,  $< 1$  mm diameter; fine, 1 to 2 mm diameter; medium, 2 to 5 mm diameter; and coarse, 5 mm diameter or larger. Quantity classes are defined in terms of numbers of each size per unit area -  $1 \text{ cm}^2$  for very fine and fine roots and  $1 \text{ dm}^2$  for medium and coarse roots. All roots smaller than 10 mm diameter are described in terms of the above quantity classes; roots  $> 10$  mm diameter are described separately. See Boulding, (1991), A Field Pocket Guide, for charts estimating root sizes.

The location of roots within a soil layer is described in relation to other features of a soil horizon or described layer. Relationships to soil layers, animal traces, pores and other features are among those to be noted, and to include whether roots are inside peds or only follow parting planes between peds. The overall impression of the root system, as indicated in the soil profile, their distribution and pattern of growth and, depth of penetration should be additionally noted. Root distribution

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varies with the type of plant, with the stage of growth and sometimes with plant variety. Other than root-soil, root-mineral, root-macro, meso, and microbiota interactions, and adsorptive phenomena, roots promote the translocation of water, and provide interfaces for transport of chemicals through the soil system. See vegetation typical for various climatic regimes in regards to expected kinds of roots, their sizes, development, pattern, distribution, extent, and soil associations. For further details consult the above references.

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VALUE: Common

DEFINITION: 1 to 5/cm<sup>2</sup> for fine and very fine roots; 1 to 5 dm<sup>2</sup> for medium and coarse roots.

CONDITIONS: A number of kinds of roots are observable, depending on vegetation types and distribution, soil conditions, and other relationships as described above. If vegetation is spotty, then statistical methods should be used to estimate the quantity of roots per unit area. Note if there are any environmental effects including wastes, on vegetation and soil relative to root quantity and size as well as their location and distribution. Compare to off-site areas.

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VALUE Few

DEFINITION: < 1/cm<sup>2</sup> for fine and very fine roots;  
< 1/dm<sup>2</sup> for medium and coarse roots.

CONDITIONS: There are few observable roots per specified area either because of a limiting natural environment - climate, water availability, soil conditions, etc. - or presence of toxic or hazardous wastes have had an effect on restricting plant germination, growth, development, and distribution. Note any remnants of possible previous vegetation or effects on present site vegetation. Site analysis for contaminants and root effects should be compared with off-site analyses.

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VALUE: None

DEFINITION: No viable roots.

CONDITIONS: There are no discernible living roots in the soil system, although dead or decaying roots may be evident. As for other roots, they may be described accordingly, but with the notation as to their morbidity or state of decay. In some "healthy" soil

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systems, no roots may be found in a specified area, especially if climatic conditions or other external conditions severely limit or prohibit plant growth, e.g., extreme and barren deserts, dune soils, salt flats, newly laid down volcanic or alluvial materials, etc. For toxic and hazardous waste sites there may no longer be any viable roots, or depending on the nature, concentration, release, and translocation of toxic chemicals and ions, the roots may be affected in sporadic areas in the site or slowly responding to contaminated site conditions. Absence of viable roots should be compared with off-site areas and analyses of soil contaminants.

## OBJECT/ATTRIBUTE: SOIL/STRUCTURE GRADES

DEFINITION: A grouping or classification of soil structure (the combination or arrangement of primary soil particles into secondary particles, units or peds) on the basis of inter- and intra-aggregate adhesion, cohesion, or stability within the profile.

VALUES: STRUCTURELESS  
WEAK  
MODERATE  
STRONG

CATEGORY: SITE BACKGROUND

PROPERTIES: INPUT FACT

REFERENCES: Mason, 1983b, pp. 5-15 to 5-19  
USDA Soil Conservation Service, 1981, pp. 4-70 to 4-74  
USDA Soil Conservation Service, 1975, pp. 474-476

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VALUE: Structureless

DEFINITION: No observable aggregation or no definite and orderly arrangement of natural lines of weakness. Massive if coherent. Single grain if noncoherent.

CONDITIONS: Soil structure greatly influences the growth of plants, the retention and movement of solutes, and is needed for determining the classification of soils.

Surface structure can greatly modify the ability of water and liquid chemicals to penetrate into the soil. Structure may vary or show gradations between horizons and with depth. It may modify the influence of texture in regard to moisture and air relationships. The type of structure determines the dominant direction of the pores and the subsequent direction of water movement in the soil profile. Structure with large macropores will have a considerable effect on movement of water and liquid chemicals through the soil profile. Also see knowledge frames for soil horizons. A massive soil could be represented by a thick, dense, plastic clay layer. A single-grain structure is represented by a loose, noncoherent sand. Sorption of metal species depends on factors other than a well-defined structure, e.g., amounts and associations of clay, organic matter, salts, pH-Eh, etc.

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VALUE: Weak

DEFINITION: Poorly formed, indistinct peds (natural occurring crumbs, prisms, or blocks in contrast to clods, formed artificially), barely observable in place.

CONDITIONS: For soils having structure, the shape, size and grade (distinctiveness of peds) are described. See comments below for shape and size. For disturbed soils, grades are generally more evident than shape or size. A weak soil structure modifies the ability of water and liquid chemicals to penetrate into the soil and to percolate through the soil to a lesser degree than a structureless soil. Soils are less massive, but could still be affected by clay layers. Single-grained structures may show some cohesion, such as by organic or inorganic interstitial (between grains) materials.

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VALUE: Moderate

DEFINITION: Well-formed, distinct peds, moderately durable and evident, but not distinct in disturbed soil.

CONDITIONS: Soil aggregation and cohesion are evident, along with crumb formation as under vegetation. Percolation and infiltration are enhanced with increased opportunity for mobility and transport of ions under leaching conditions. There is greater potential for metal species to be affected by structure of soils.

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VALUE: Strong

DEFINITION: Durable peds are quite evident in undisturbed, unmanipulated soils. Peds adhere weakly to one another, withstand displacement, and become separated when the soil is disturbed.

CONDITIONS: Considerable aggregation, such as under grasses, forms an open, porous soil, promoted by some aggregation of clays, saturating ions, and especially organic matter. The crumbly or granular and friable open structure has open channels that lead to lower soil horizons and facilitate water and chemical infiltration and penetration into the soil.

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Field terminology for soil structure consists of separate sets of terms designating each of the three properties, which by combination form the names for structure. See Boulding, (1991), A Field Pocket Guide, for illustrations of soil structure shapes

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and sizes. The Soil Conservation Service gives the following notations for soil structure shapes and sizes:

Shape: Several basic shapes of peds are recognized in soils. Supplemental statements about the variations in shape of individual peds are needed in detailed descriptions of some soils. The following terms describe the basic shapes and related arrangement of peds:

Platy: The peds are flat and plate-like. They are generally oriented horizontally and are usually overlapping. A special form, lenticular platy structure, is recognized for plates that are thickest in the middle and thin toward the edges.

Prismatic: The individual peds are bounded by flat or slightly rounded vertical faces. Peds are distinctly longer vertically, and the faces are typically casts or molds of adjoining peds. Vertices are angular or subrounded; the tops of the prisms are somewhat indistinct and normally flat.

Columnar: The peds are similar to prisms and are bounded by flat or slightly rounded vertical faces. However, the tops of columns, in contrast to those of prisms, are very distinct and normally rounded.

Blocky: The peds are block-like or polyhedral. The peds are bounded by flat or slightly rounded surfaces that are casts of the faces of surrounding peds. Blocky peds are nearly equidimensional but grade to prisms, which are longer vertically, and to plates, which are longer horizontally. The structure is described as angular blocky if the faces intersect at relatively sharp angles and as subangular blocky if the faces are a mixture of rounded and plane faces and the angles are mostly rounded.

Granular: The peds are approximately spherical or polyhedral and are bounded by curved or very irregular faces that are not casts of adjoining peds.

Size: Five classes are used to describe the size of peds: very fine, fine, medium, coarse, and very coarse. The size limits of the classes differ according to the shape of the peds. The classes of size for the various ped shapes are given in Table 4-3. The size limits refer to measurements in the smallest dimension of plates, prisms, and columns and to the largest of the nearly equal dimensions of blocks and granules.

In some soil horizons the peds are very much larger than the minimum size given for the very coarse class. If the peds are more than twice the minimum size of "very coarse", the actual size is given: "prisms 30 to 40 cm across."

Table 4-3. Size Classes of Soil Structure. (From USDA SCS, 1981)

Size Classes	Shape of Structure			
	Platy <sup>a</sup> (mm)	Prismatic and Columnar (mm)	Blocky (mm)	Granular (mm)
Very fine	<1	<10	<5	<1
Fine	1-2	10-20	5-10	1-2
Medium	2-5	20-50	10-20	2-5
Coarse	5-10	50-100	20-50	5-10
Very Coarse	>10	>100	>50	>10

<sup>a</sup> In describing plates, "thin" is used instead of "fine" and "thick" instead of "coarse".

## OBJECT/ATTRIBUTE: SOIL/SURFACE FEATURES

DEFINITION: Conspicuous features on the soil surface that may be examined and described, including not only natural features, but distinct artificial features introduced through human activities.

VALUES: PROMINENT  
DISTINCT  
FAINT

CATEGORY: SITE BACKGROUND

PROPERTIES: INPUT FACT

REFERENCES: USDA Soil Conservation Service, 1981, pp. 4-74 to 4-76

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VALUE: Prominent

DEFINITION: Surface features are conspicuous, without the need for magnification, when compared with other smooth, featureless, or unbroken surfaces.

CONDITIONS: Soil texture, color, stress formations, thickness of features, coatings, packing and orientation, amount, location and other properties or combination of properties contrast sharply with properties of the adjacent material, or the feature is thick enough to be conspicuous. Surface features, artificial or natural, when distinct, need to be determined for effects and interference in soil sampling and distribution of chemicals. If surface materials are coated with chemicals, they should be separated or removed before proceeding with sampling. Soil-liquid state should be noted because some surface features change markedly as the amount of liquids changes. There may be considerable effect on distribution and concentration of contaminants.

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VALUE: Distinct

DEFINITION: Surface features can be detected without magnification, although magnification or additional tests may be needed for positive identification.

CONDITIONS: A feature or features contrast enough with the adjacent materials that differences in texture, color, or other properties are evident. There is less necessity to remove or

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isolate surface features before proceeding with sampling. There may be some effect on distribution and concentration of contaminants.

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VALUE: Faint

DEFINITION: Surface features are evident only upon close examination with 10x magnification, and cannot be identified positively in all places without greater magnification.

CONDITIONS: Contrast with adjacent materials in texture, color, and other properties is small, and probably has not affected distribution and concentrations of contaminants, including metal species. Sampling does not generally require removal of the relatively homogeneous surface materials.

## OBJECT/ATTRIBUTE: SOIL/TEMPERATURE

DEFINITION: The degree of heat of a given body of soil at a particular point in time and space or during a particular period of time and at a particular depth or surface extent of soil; usually determined in °F or °C.

VALUES: HIGH  
MEDIUM  
LOW

CATEGORY: SITE BACKGROUND

PROPERTIES: INPUT FACT

REFERENCES: Hillel, 1982, pp. 155-175  
Fluker, 1958, pp. 35-46  
Taylor and Jackson, 1986  
Thompson and Troeh, 1978, pp. 72-77  
US DOE, 1987, Appendix E, Section E4.5.1, p. E-129

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VALUE: High

DEFINITION: Thermal measurement(s) taken on the surface or with depth of soil, at a point in time, or over a period of time, with temperatures at or > 38 °C (100.4 °F).

CONDITIONS: Temperature changes within the contaminated site can occur due to the temperature of materials added, redistribution of heat by intruding extraneous water, and heat generated by waste decomposition (biological and physical/chemical activity). Temperature is important because it influences reaction rates between the liquid (water or liquid chemical) and solid (soil) medium. Moreover, it exerts an influence on microbial catalysis. Both solubility rates and microbial activity increase as temperatures rise.

Soil temperature measurements are generally of value only if measured over a period of time, at least for several diel periods. Temperature measurements may be of value in locating local hot spots where temperature is elevated by chemical (or biological) activity. Comparisons may be made at off-site locations. Normal high temperatures are characteristic of thermic and hyperthermic soil temperature regimes. High surface or near-surface temperatures also may be recorded for other less thermic soils, depending upon season of the year, weather, exposure and slope, soil color, composition, amount and distribution of vegetation, and amount

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and distribution of moisture. Contaminant spread and movement, as well as biodegradation, is greatly affected by high soil temperature, especially if moisture is available. Correlative information is necessary for interpretation of soil temperature measurements. The spread, movement, and biodegradation of contaminants should be cautiously interpreted if it is based solely upon soil temperature measurement, especially at a single point and time.

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VALUE: Medium

DEFINITION: Thermal measurement(s) taken on the surface, or with depth of soil, at a point in time, or over a period of time with temperatures 8°C (46.4 °F) to 38° (100.4°F).

CONDITIONS: The same factors as for high temperature soils apply to soils with moderate temperatures, except as one or more factors can predominately affect soil temperature readings. These factors should be noted and recorded (e.g., dark, barren, unshaded, moist soil, high in organic matter, with high incidence of solar radiation during mid-day and midsummer).

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VALUE: Low

DEFINITION: Thermal measurement(s) taken on the surface, or with depth of soil, at a point in time, or over a period of time, with temperatures predominately < 8 °C (46.4 °F), or lower.

CONDITIONS: These are predominately cold soils with a pergelic or cryic temperature regime. Any elevation or differences in soil temperature from off-site nondisturbed soils should be noted. Depending on season, time of day, and certain site and soil characteristics, higher point or diel temperature can be recorded. These may have an immediate or short-term effect on spread and movement of contaminants, and biodegradation, especially at the surface or above the permafrost boundary. Special circumstances should be noted for any interpretation and correlation of soil temperature readings at these sites.

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OBJECT/ATTRIBUTE: SOIL/TEMPERATURE REGIMES

DEFINITION: The pattern of soil temperature fluctuations in a soil, characterized by temperature distribution with respect to depth, time, and season for a given soil at a given location.

VALUES: PERGELIC  
CRYIC  
FRIGID-ISOFRIGID  
MESIC-ISOMESIC  
THERMIC-ISOTHERMIC  
HYPERTHERMIC-ISOHYPERTHERMIC

CATEGORY: SITE BACKGROUND

PROPERTIES: INPUT FACT

REFERENCES: Fuchs, 1986  
Hadas, 1979  
Smith, Newhall and Robinson, 1960  
Soil Science Society of America, 1987  
USDA Forest Service, 1961, pp. 126-128

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VALUE: Pergelic

DEFINITION: A soil temperature regime (thermal distribution) that has mean annual soil temperatures of  $< 0^{\circ}\text{C}$ . Permafrost is present.

CONDITIONS: Knowledge and information of temperature regimes is useful in predicting both soil and contaminant behavior. Contaminant behavior, adsorption, desorption, and mobility will depend considerably on the temperature (and associated moisture) regime.

A cold environment soil: compare with site and soil development and characteristics for polar climate, low tundra-type vegetation, and low temperature dependent chemical, biotic, and microbiotic activity and processes. Permanently frozen material underlies the solum (upper part of soil profile). Upper boundary of the permafrost is coincident with the lower limit of seasonal thaw. The climate-driven soil heat flux is primarily active during the short summer and under conditions of low incidence of solar radiation, dense soil vegetative cover, and moisture. Biodegradation and movement of contamination are impeded by low temperature and the permafrost

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barrier. Penetration of contamination below the surface is limited. Contamination flow is primarily surficial. Soil Conservation Service maps are available for most of the thermic regions in the U.S.

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VALUE: Cryic

DEFINITION: A soil temperature regime (thermal distribution) that has mean annual soil temperatures of  $> 0^{\circ}\text{C}$  but  $< 8^{\circ}\text{C}$ ,  $> 5^{\circ}\text{C}$  difference between mean summer and mean winter soil temperatures at 50 cm, and cold summer temperatures.

CONDITIONS: A soil temperature regime found in latitudes, bounding or grading into polar regimes, and at lower latitudes and higher elevations inductive of alpine soils and ecosystems. Compare with climate, vegetation, and soil characteristics typical for this region. Soil dynamics, including microbial processes, are less restricted by soil temperatures and heat fluxes. Diurnal and annual periods of heat flux have a greater amplitude and to a greater depth than in pergelic soil temperature regimes. Evaporation and melting generally preceding at a more rapid rate and for a greater period than for pergelic soils. Freezing and thawing of soils may promote development of macro pores, thereby enhancing the movement of water and chemicals into the soil profile. Spread of contamination is less restricted than for soils with pergelic temperatures regimes; subsurface penetration of contamination is limited in time and space.

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VALUE: Frigid-Isofrigid

DEFINITION: A soil temperature regime (thermal distribution) that has mean annual soil temperatures of  $> 0^{\circ}\text{C}$  but  $< 8^{\circ}\text{C}$ ,  $> 5^{\circ}\text{C}$  difference between mean summer and mean winter soil temperatures at 50 cm below the surface, and warm summer temperatures. Isofrigid is the same except the summer and winter temperatures differ by  $< 5^{\circ}\text{C}$ .

CONDITIONS: A soil temperature regime found in northern temperate latitudes and developed under favorable conditions of climate, vegetation, microbial activity and processes, and other soil forming factors. Surface layers of soil may be able to acquire an appreciable amount of moisture from the atmosphere by condensation when the temperature of the air-dry soil is lower than that of the air; the reverse also may occur. Soil moisture will have a more pronounced effect on soil temperature than pergelic or cryic soils by variations in specific heat, conductance, surface evaporation, and percolation. Lower temperatures will be found in poorly drained

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soils than in well-drained areas. Soil moisture is a more important factor in relating soil temperature than in pergelic or cryic soil temperature regimes. Extent and movement of contaminants, and biodegradation processes, are increased because of more favorable site and soil temperature-moisture relations.

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VALUE: Mesic-Isomesic

DEFINITION: A soil temperature regime (thermal distribution) that has mean annual soil temperatures of 8 °C or more, but < 15 °C, and > 5 °C difference between mean summer and mean winter soil temperatures at 50 cm below the surface. Isomesic is the same except the summer and winter temperatures differ by < 5 °C.

CONDITIONS: A soil temperature regime found in southern temperate latitudes, and with moderating influences of climate, vegetation, and soil-forming factors. This soil temperature regime is indicative of more moderate temperatures, and with accompanying accelerated processes than for a frigid soil temperature regime. Opportunities for spread and movement of contaminants are more likely unless soil conditions (e.g., poor structure) impede movement.

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VALUE: Thermic-Isothermic

DEFINITION: A soil temperature regime (thermal distribution) that has mean annual soil temperatures of 15 °C or more but < 22 °C, and > 5 °C difference between mean summer and mean winter temperatures at 50 cm below the surface. Isothermic is the same except the summer and winter temperatures differ by < 5 °C.

CONDITIONS: These regimes include some thermogenic soils, with properties that have been influenced primarily by high temperatures as a soil-forming factor. They are developed in subtropical and equatorial regions. Compare with climate, vegetation, and soil characteristics for these regions. With moisture available, and other favorable site and soil characteristics, movement of contaminants can be rapid.

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VALUE: Hyperthermic-Isohyperthermic

DEFINITION: A soil temperature regime (thermal distribution) that has mean annual soil temperatures of 22 °C or more and > 5 °C difference between mean summer and mean winter soil temperature at 50 cm below the surface. Isohyperthermic is the

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same except the summer and winter temperatures differ by  $< 5^{\circ}\text{C}$ .

CONDITIONS: These regimes are predominately thermogenic soils, with properties that have been influenced primarily by high temperatures, unmoderated by extensive periods of moisture, as a soil-forming factor. They are developed in arid and hot desert regions. Compare with climate, sparsity of vegetation, and soil characteristics for these regions. Unless sufficient moisture becomes available, spread of contaminants is restricted by soil characteristics, and vertical flow is impeded unless soil texture is loose and structure is favorable for movement of contaminants. Biodegradation is rapid under favorable circumstances (e.g., nature of contaminant, energy, and nutrient supply).

## OBJECT/ATTRIBUTE: SOIL/TEXTURE CLASSES

DEFINITION: The relative proportions of the various soil separates < 2.0 mm diameter (mineral particles of sand, silt, and clay) and described into textural classes on the basis of the proportions of the various separates present.

VALUES: FRAGMENTAL  
SKELETAL  
SANDS  
LOAMS  
SILTS  
CLAYS  
ORGANIC SOILS

CATEGORY: SITE BACKGROUND

PROPERTIES: INPUT FACT

REFERENCES: ASTM D, 1988a, 422-63, pp. 85-86; 87-93; 293-303.  
Dixon and Weed, 1977  
Foth, et al., 1971, pp. 6-11  
Gee and Bauder, 1986  
Jackson, Lim and Zelazny, 1986, pp. 101-150  
Mason, 1983b, pp. 5-7 to 5-12  
Soil Science Society of America, 1987  
USDA Forest Service, 1963, pp. 105-115  
USDA Soil Conservation Service, 1983, pp. 603-4 to 603-13  
USDA Soil Conservation Service, 1975, pp. 469-475  
USDA Soil Conservation Service, 1970, pp. 18-20  
US EPA, 1988a, pp 5.A.2 to 5.A.13

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VALUE: Fragmental

DEFINITION: Any soil or textural composition in which 30% or more of the materials are > 2 mm diameter; various size groups of individual soil grains of clay and silt and sand are < 2 mm diameter; not a distinct soil textural class.

CONDITIONS: The principal textural classes in soil, in increasing order of the amount of silt and clay, (Soil Science Society of America, 1987) are as follows: Sand, loamy sand, sandy loam, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, and clay. These class names are modified to indicate the size of the

sand fraction or the presence of gravel, cobbles, and stones. For example, terms such as loamy fine sand, very fine sandy loam, gravelly loam, stony clay, and cobbly loam, are used on detailed soil maps. These terms apply only to individual soil horizons or to the surface layer of a soil type (map unit). (See "Note" at the end of this frame in regard to classification scheme presented in A Field Pocket Guide (Boulding, 1991.)

Gravelly, cobbly, stony, or bouldery sites may be encountered in the field, such as in moraines, mountain soils, and eroded areas, or disturbed areas such as construction sites, gravel pits, waste disposal sites, and mined sites. Rarely are such areas used for agricultural purposes. They may have been used for disposal of hazardous materials as a convenience, or because of their low economic value and use for any other purpose. Such sites may have been used for a distinct waste repository site, with direct evidence of dumpage--containers and liquids. Contaminants may accumulate around gravels, cobbles, etc., as well as saturate the underlying and intermixed soil, bedrock, and aquifer or drainage system, both surface and subsurface. Stony soils are good conductors of heat and tend to make heavy, dense soils more permeable to water and air, thereby hastening biodegradation. If scattered on the surface, stony materials may serve as barriers to evaporation of fluids and increase soil moisture retention at the soil surface and with depth. Stones tend to increase channeling and passageways around them, and thereby increase infiltration of contaminating fluids into the soil itself. Contamination is easily and rapidly spread in loose, noncohesive sandy soils. Biodegradation can be rapid if energy substrate and nutrients and other soil conditions are favorable.

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VALUE: Skeletal

DEFINITION: Mineral grains, resistant siliceous and organic bodies larger than colloidal size.

CONDITIONS: This grouping represents minerals and organics comprised of individual grains that are relatively stable, not readily translocated, are concentrated or reorganized by soil-forming processes. It is not in accordance with a designated SCS textural class, but is included here as defined because of its significance to possible accumulation and concentration and/or release of hazardous waste solutes, including metals on the surfaces of skeletal grains and bodies. These particles can have important effects on various physical and physicochemical soil properties and behavior. Mineral grains, in addition to quartz, could be represented by carbonates, halides, sulfides and sulfates, which are more commonly associated with soils of alkaline reaction but have relatively high solubilities and rates of dissolution compared to silica minerals in soils.

In acid sulfate soils, depending on whether the reaction is reduction or oxidation (moderated by microorganisms), sulfides are produced under reduction, and acid under oxidation. Sulfidic sediments are commonly silty clays or silty clay loams high in organic matter. Peats are often associated with sulfidic sediments and with a sulfidic accumulation in the mineral soil just beneath the contact with the peat. If sulfides sediments are drained then the oxidation phase of acid sulfate soil formation commences. These are important reactions for the behavior, dissolution and the potential for migration of sorbed soil metals.

Silica, and tectosilicates, e.g., feldspar, exert a secondary influence on most physicochemical properties in soils, including surface area, ion exchange, moisture retention, plasticity, cohesion, shrink-well, and porosity. They serve as a dilutant to the much more reactive clay mineral components. Silica minerals, in general, have little surface charge and the specific surface area is also small. Silica surfaces are not highly hydrated. Except when silica particles are cemented together by organic matter, sesquioxides (iron and/or aluminum), silica, carbonates or other cementing agents, the cohesive forces binding the particles together are relatively weak. As the silica content of cohesive soils increases, then adhesion, cohesion, shrink-swell, CEC, surface area, moisture retention, plasticity limits, capillary fringe, compression and compaction decrease.

The hydrous oxides of iron, manganese and aluminum are quite common in soils, occurring as crystalline minerals or as surface coatings on other minerals. They are characterized by a very high surface area to weight ratio and are frequently amorphous (without definite form). Many hydrous oxide surfaces generate a significant number of positive charges as the pH decreases. Hydrous oxides provide important adsorption surfaces for metal contaminants and are therefore important to the retention of heavy metals in soils. Metal ions tend to become unhydrolyzed as the pH decreases.

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VALUE:	Sands
DEFINITION:	Depending upon the classification scheme (USDA), sandy, or coarse-textured soils are 50 to 100% particle sizes between 2.0 mm and 0.05 mm diameter as determined by graded sieves. Individual particles feel gritty when the soil is rubbed between the fingers. Not plastic or sticky when moist.
CONDITIONS:	Coarse textured soils (sands and loamy sands) are usually loose and unstable, and are very susceptible to wind erosion. Individual grains can be easily seen or felt. If squeezed in the hand when dry, the soil will fall apart when the pressure is released (the hand is opened). If squeezed when moist, the soil will form a discernable cast,

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but will crumble when touched. They are highly permeable, and infiltration and movement of liquids is rapid under gravity flow.

Contamination is easily and rapidly spread in loose, noncohesive sandy soils. Biodegradation can be significant if substrate, energy, nutrients, and other soil conditions are favorable. See Soil Texture Triangle for all textured grades.

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VALUE: Loams

DEFINITION: This textural class is for soils having a moderate amount or mixture of sand, silt and clay. Loamy soils are an intermediate textural class. They contain between 7 to 27% clay; 28 to 50% silt, and < 52% sand. Depending upon the percentages of sand, silt and clay, loams form poor to medium ribbons when moist, and medium to soft clods when dry. Loams feel somewhat gritty, yet are fairly smooth and plastic.

CONDITIONS: Soils are usually a mixture of textural classes of sands, silts and clays, and a few % organic matter. Loams range from moderately course-textured to moderately fine-textured soils. They constitute more than half of textural soils. Most soils of agricultural importance are some type of loam, and constitute soils of generally favorable physical characteristics for crop production. Loams tend to moisten quickly to moderately, penetration is relatively easy, infiltration and percolation are relatively quick to moderate, and the soil tills easily. There is moderate to relatively fast movement of contaminants, both surface and subsurface, which makes it difficult to confine fluids in these soils. Contamination of these soils, particularly in agricultural areas, is to be avoided.

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VALUE: Silts

DEFINITION: Individual mineral particles of these soils range in diameter between the upper size of clay, 0.002 mm, and the lower size of very fine sand, 0.05 mm. Soils of these textural classes contain 40% or more silt. A silt soil contains 80% or more of silt, and < 12% clay. Silts feel smooth and powdery when rubbed between the fingers. They are only moderately plastic or sticky when moist, and have a floury feel when dry or pulverized.

CONDITIONS: Silts are generally medium to moderately fine-textured soils, not as loose as sandy soils, nor as tight as clay soils. They form moderate to hard clods when dry, depending upon the percentages of sand and clay. Infiltration, penetration and

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movement of liquids is not as rapid as for loams. Silts are more dense, less well aerated and may be more poorly drained than sandy soils or loams. Silts are composed of minerals resistant to weathering, but to a lesser degree than sands. Retention of contaminants, including metal species, on silt-size particles is increased compared to loams or sands.

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**VALUE:           Clays**

**DEFINITION:**   Clayey soils are heavy-textured soils containing 27% or more of clay materials. A clay soil itself is defined as containing 40% or more of clay, < 45% sand, and < 40% silt. The particle size range for clays is < 0.002 m or less. The moist soil is plastic, pliable, and feels sticky. When moistened it can be easily molded to form a wire-like ribbon. Clays feel smooth and not gritty to the touch.

**CONDITIONS:**   Clays are the finest textured of all the soil classes. Clays feel smooth and not gritty to the touch. Although they contain the greatest percentage of pore space, the pore diameters are extremely small, thereby restricting the flow of liquids. There is a high capacity for retention and exchange of ions and nutrients, and considerable effort is necessary to solubilize and remove contaminants. Leaching of clays is a considerable problem, and especially for the iron and aluminum hydrous oxide clays found in the tropics. The silicate clays of temperate regions (kaolinite, montmorillonite and illite) also present considerable difficulties. Bioremediation is restricted in clay soils because of such factors as poor aeration and movement of liquids, and especially if drainage is impeded.

As for all textured class determinations, if a more precise determination is desired to determine the amounts of sands, silts, and clays, then appropriate samples should be collected for determination of particle size distribution. Analysis can be made by the hydrometer or pipette method, and with subsequent reference to a soil textural triangle for textural class. See Soil Clay Minerals for further information.

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**VALUE:           Organic Soils**

**DEFINITION:**   A soil composed of 30% organic matter or more; not a mineral soil textural class; may have an oily feel, may stain the fingers, and may release water if squeezed when saturated.

**CONDITIONS:**   Organic soils are generally saturated with water for prolonged periods and in various stages of decomposition. The remainder of the soil separates are clay, sand and silt

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fractions. Peats, bogs, mucks, tundra and forest soils may contain a high percentage of organic matter. The most obvious and significant addition of forest soils is organic matter, primarily as soil surface litter; in grasslands, the major additions are from roots. In local areas, atmospheric components such as SO<sub>x</sub> and NO<sub>x</sub>, along with heavy metals may be added to the soil organic matter. Chelation of heavy metals with soil organic matter can increase their toxicity. The colloidal material of organic matter has a great capacity to hold liquids, as well as nutrient and contaminant metal ions, thereby increasing potential toxicity of sorbed contaminants. Contaminants are spread primarily by wind and water, and especially if vegetation is killed and the soil exposed to erosional forces. Leaching will remove contaminants in the soil solution and in suspension. Depending on the nature of the contaminant, biodegradation may be impeded or accelerated in organic soils.

The organic matter itself is continually subject to decomposition by microorganisms, unless toxic, and is generally in an active state of decay. Organic soils are not included in the soil textural triangle or usually determined by method of feel. In the field, it can best be estimated by visual examination of the soil sample, and by application of an oxidizing agent, such as peroxide. See knowledge frame on Soil Organic Matter for further details.

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Note: In A Field Pocket Guide (Boulding, 1991), the particle size classes for textural differential of soils at the family level are as follows:

**Fragmental** - Stones, cobbles, gravel, and very coarse sand particles with too little fine earth to fill some of the interstices larger than 1 mm in diameter.

**Skeletal** - Rock fragments make up 35 percent or more by volume. The dominant fine earth fraction (sandy, loamy or clayey is used as a modifier).

**Sandy** - Texture of fine earth is sand or loamy sand with <50% very fine sand; clay <35%; rocks <35%.

**Loamy** - Texture of fine earth is very fine sand or finer; clay <35%; rocks <35%. Subdivisions include coarse-loamy, fine-loamy, coarse-silty, and fine-silty.

**Clayey** - Texture of fine earth is >35% clay; rocks <35%. Subdivisions include fine and very fine.

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## SECTION 5.0

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## APPENDIX A

### SOURCES OF SITE CHARACTERIZATION DATA

Any soil sampling effort at a hazardous waste site requires knowledge of the site. Too often, however, not enough time is spent in determining the historical data sources (and resources) and obtaining the preliminary information and data necessary to adequately plan and undertake a reliable soil sampling effort.

A thorough investigation of available data and information, followed by data review and evaluation, should be conducted as early as possible in the project and prior to soil sampling. By reviewing historical site information, conducting site visits, interviewing area residents and knowledgeable personnel at facilities, agencies, and other organizations, a good grasp of the site and situation can be obtained for sampling purposes. Procurement and review of this available background information is a logical and essential first step in planning the site activities, and can often assist in the selection of analytical methods and in the preparation of reports.

Initially, the researcher should look for information that provides an overview of the site relationship to the regional setting and the pollutant problem. It is important to look at the data in the context of the soil ecosystem at the site, relative to potential sampling activities. The historical data should help answer questions about the sources of pollution, routes of migration, and uses of the site and area. The types of data will vary with the site, but, in general, should deal with the history of site and area use; surface and subsurface characteristics; historical drainage patterns; soil types; root and vadose zone characteristics; ground-water drainage pattern, flow, and use; and the environmental and health problems associated with safety hazards.

Some typical sources and types of data useful in a systematic assessment of waste disposal sites are shown in the table below.

<u>Type of Data</u>	<u>Typical Sources</u>
Property Survey	County Records, Property Owner; various County/City Planning/Zoning Commission Departments
Well Driller's Logs	Well Driller, Property Owner, State Records
Water Level Measurements	Well Owner's Observations, Well Driller's Logs, Topographic Maps, Ground Water Maps (Reports)
Topographic Maps	U.S. Geological Survey and Designated State Sales Offices

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<u>Type of Data</u>	<u>Typical Sources</u>
Air Photos	U.S. Geological Survey, US. Department of Agriculture, U.S. Forest Service, Companies Contracted by County and City Governments
County Road Maps	State Agencies
Ground-Water Reports	U.S. Geological Survey, State Agencies
Soil Surveys of Counties/ Parishes (Louisiana)	US. Department of Agriculture
Geologic Maps	U.S. Geological Survey and State Surveys
Climatological Data	National Oceanic and Atmospheric Administration
RCRA permits and Applications	US. EPA and State Environmental Offices
Local History, Reports, Information	City Offices
Local Soils, Geology, Water Levels, Regulations	Contractors
Reference Data and Bibliographies	Computer Data Bases
Process, Hazards, Protective Equipment Needs	U.S. Department of Labor Occupational Safety and Health Administration (OSHA)
Liquid waste types Production Information, Treatment Processes	National Pollution Discharge Information System (NPDS)
Location of buried lines	Utility Companies: Gas, Electric, Water, Petroleum, or Natural Gas Pipelines

These sources can provide useful information for developing, planning, and implementing soil sampling procedures, guidelines, and protocol for a particular site. Available data may include previous environmental studies, on-site inspections, and facility operations and disposal practices. Site descriptive information may be available on terrain, topography, physiography, soils/geology,

ecology, biota, climate/weather, surface and ground water, contaminant characterization, and sensitive receptors.

Sampling and sample handling are crucial elements for any subsequent examination and analysis of soil samples obtained in the field. Some analyses can only be performed in the laboratory; therefore, soil samples must be procured for this purpose. Special care must be taken in sampling, handling and storage for some analyses, e.g. microbiota. Sampling equipment procedures and methods are not included in this document. They are included in the ESES document and should be referred to for that purpose. Additional information is provided in Boulding (1991), A Field Pocket Guide. The following references, which include those for sampling soils contaminated with hazardous wastes, may be useful.

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For soil sampling information, particular attention should be given to the Soil Conservation Service (SCS) and Soil Survey staff, along with the Agricultural Stabilization and Conservation Service, and state and county cooperative extension services. All of these agencies have frequent and continued contact with the local community and are often informed about rural areas. They should have a knowledge of the soil ecosystem, local soils, and its responses (e.g., flooding, use, and movement). They are usually qualified to assist in obtaining the kinds of information needed in regard to history of the area and the presence and effects of pollution. They are also valuable sources for identifying local historians: local citizens and authorities such as fire, police, health, engineering, highway and maintenance departments, tax and legal departments and officers, forestry and conservation workers, and wildlife biologists. Information also may be gathered from these sources about prior land use. The local fire department can often provide information on the nature and movement of spilled materials, which is especially important for any countermeasures taken on unusually toxic materials. Other City offices, such as the Chamber of Commerce, can provide information about local industries, principal products and facility addresses.

Most states have an agricultural college that is closely aligned with the U.S. Department of Agriculture. The Soils and Agronomy departments of the Land Grant universities often work closely with the SCS and extension services, and are involved in agricultural soils analyses. Their files often contain valuable information on the nature of soils in an area, and they may know about past and present problems, including soil pollution, and any remedial measures taken.

The U.S. Geological Survey (USGS) is another valuable source of information for technical geological and hydrologic reports, maps, aerial photographs, and water monitoring data. Frequently, the geologist working on a vadose or ground-water problem, surficial or bedrock geological mapping, will have information on soil properties and pollutant migration. The well driller's log books, which are kept when exploratory borings are made for highway or building construction, can augment the data collected by soil investigators. The USGS, along with the Corps of Engineers and Bureau of Reclamation, maintains information on flooding, stream conditions, and stream flow, which is important in determining the rate and route of pollution migration.

EPA, or one of its state counterparts, should always be consulted, particularly to determine if pollution at the site is being investigated, and if there are analyses and other data that should be reviewed before sampling at the site. The EPA and State Environmental Office will have information on RCRA permits and applications. In addition, state environmental, resource, and health agencies should be consulted. Useful data may be archived at their offices.

Environmental Impact Statements (EISs) are particularly valuable, providing information on soils properties and land use. A review of EISs can aid planning and thereby decrease the cost of the proposed study, as well as enhance the effectiveness of the soil sampling plan.

Aerial photographs and remote sensing imagery obtained by aircraft or satellite can be valuable in determining the impacts of pollutants and in identifying routes and effects of migration. One of the best historical records available of old landfill sites is the archived aerial photographs. Remote sensing imagery can also provide information on drainage patterns, land use, vegetation stress, historical land development, and geologic structure.

EMSL-LV is one of the best resources available for pollution-oriented imagery and photographs. Taken in conjunction with accidents or chemical spills, these photographs are a valuable resource for determining where samples should be taken on the site. If necessary, current photography is obtained from overflights, as part of a preliminary assessment. The following sources can often provide information on available imagery.

Agricultural Stabilization and Conservation Service  
Bureau of Reclamation  
Colorado River Commission  
EROS Data Center  
National Aeronautics and Space Administration  
National Archives and Record Service



National Oceanic and Atmospheric Administration  
National Park Service  
National Weather Service  
Tennessee Valley Authority  
U.S. Air Force  
U.S. Army Corps of Engineers  
U.S. Army Map Service  
U.S. Coast and Geodetic Survey  
U.S. Commodity Stabilization Service  
U.S. Forest Service  
U.S. Geological Survey  
U.S. Department of Agriculture, Soil Conservation Service

Sources of data obtained should be properly documented to ensure later confirmation that the data are of a quality and reliability appropriate to their intended use.

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## APPENDIX B

### GENERAL DEFINITIONS: SITE AND SOIL CHARACTERIZATION

This appendix provides definitions and terminology for characterizing the place, scene or point of study and examination of the environment containing wastes and contaminants; the spatial location and extent of surface and subsurface features; and also temporal description during the period of study. Also, see Section 5, References Cited, for sources used for general directions.

**ABANDONED HAZARDOUS WASTE SITE** - See uncontrolled hazardous waste disposal site.

**ABSORPTION** - (i) In biology, the net movement (transport) of water and solutes from outside a cell or an organism to the interior. (ii) In chemistry, the taking up of matter in bulk by other matter, as in dissolving of a gas or liquid, e.g., within the lattice structure of soil clay particles.

**ACID-BASE REACTION** - (i) The reaction of the solvent cation with the solvent anion; (ii) A chemical reaction involving a base and an acid, e.g., in a soil solution or on a clay particle upon addition of an acidic or basic substance.

**ACID CLAY** - A clay that gives off hydrogen ions when it dissolves in water.

**ACID SOIL** - Soil with a pH value < 7.0. An extremely acid soil is pH value < 4.5. A slightly acid soil is pH value 6.1 to 6.5. See soil reaction.

**ACTINOMYCETES** - A group of microorganisms usually possessing very fine hyphae or threads, classified with bacteria or fungi. Various kinds cause decomposition, cause disease, or produce antibiotics. See microflora.

**ACUTELY HAZARDOUS WASTE** - Commercial chemical products and manufacturing intermediates having the generic names listed in 40 CFR 261.33; off-specification commercial chemical products and manufacturing chemical intermediates which, if they met specifications, would have the generic names listed; and any residue or contaminated soil, water, or other debris resulting from the cleanup of a spill of any of these substances.

**ADSORPTION** - The process by which atoms, molecules or ions are taken up and retained on the surface of solids by chemical or physical binding, e.g., the adsorption of cations by negative charged minerals.

**AERATED SOIL** - A soil that allows or promotes exchange of soil gases with atmospheric gases. The rate of aeration depends largely on the volume and continuity of air-filled pores within the soil.

**AERATION POND** - A fluid-holding pond with provisions to aerate its contents by bubbling air or another gas through the liquid or by spraying the liquid into the air. See hazardous waste surface impoundment.

**AEROBIC** - (i) Having molecular oxygen as a part of the environment. (ii) Growing only in the presence of molecular oxygen, as aerobic organisms. (iii) Occurring only in the presence of molecular oxygen (said of certain chemical or biochemical processes such as aerobic decomposition).

**AESTHETICS** - Individual perceptions of any activity or situation indicating a change in the quality or a distinguishable characteristic of the perceived environment. (Perceived through the senses: sight, taste, smell, hearing, and touch.) Can be quantified or semiquantified by instrumental means, including photography.

**AGGREGATE** - A unit of soil structure, usually formed by natural processes in contrast with artificial processes, and generally < 10 mm in diameter.

**AGRICULTURAL POLLUTION** - The liquid and solid wastes from farming, including runoff and leaching of pesticides and fertilizers; erosion and dust from plowing; animal manure and carcasses; and crop residues and debris.

**AGRICULTURAL SOILS** - Soils that are cultivated to produce food or fiber, and for the raising of livestock. Can include forests and rangeland soils.

**AGROHYDROLOGY** - The science dealing with the distribution and movement of water and soil solution to and from the saturated root zone (in agricultural lands).

**AGRONOMY** - The branch of agriculture dealing with field crop production and soil management.

**AIRBORNE SURVEY** - An aerial survey, remote sensing, or other photographic means used to obtain site characteristics, e.g., nature, distribution and "health" of vegetation. See ground data.

**AIR DRY SOIL** - The state of dryness of a soil which is at equilibrium with the moisture (water) content of the surrounding atmosphere.

**ALGAE** - Simple rootless plants that grow in sunlit waters in relative proportion to the amounts of nutrients available. They can affect water quality adversely by lowering the dissolved oxygen in the water. They are food for fish and small aquatic animals,

**ALKALI METALS** - Elements (Group I) that are highly basic, i.e., lithium, sodium, potassium, rubidium, cesium and francium. The alkali metals react very readily, are the most electropositive of all the metals, always form ionic compounds (except for lithium in rare instances) and have only one oxidation state, + 1. Compare with alkaline earth metals.

**ALKALINE EARTH METALS** - Elements (Group II) that have noble gas cores and two electrons in the valence shells of their atoms. They exhibit only one oxidation state, +2. Elements include beryllium, magnesium, calcium, strontium and barium. With the exception of beryllium, these elements almost exclusively form ionic compounds. Compare with alkali metals.

**ALKALINE SOIL** - Any soil having a pH > 7.0 or > 7.3; strongly alkaline, pH > 9.0. See soil reaction.

**ALLOCHTHONOUS MATERIALS** - Materials formed, produced or occurring elsewhere than in place; of foreign origin or introduced.

**ALLOCHTHONOUS MICROBIOTA** - Microorganisms that are not indigenous to the soil, but that enter in precipitation, diseased tissues, manure, sewage, wastes, etc. They may persist for some time but do not contribute in a significant way to ecologically significant transformations or interactions.

**ALLOTROPES** - Different forms of the same element in the same state, e.g., arsenic and antimony, have stable metallic forms and less stable nonmetallic allotropes.

**ALLOY** - An intimate mixture of two or more metals or metals plus nonmetals in a substance that has metallic properties.

**ALLUVIAL SOILS** - Soils developed from recently deposited alluvium and showing little or no profile development.

**ALLUVIUM** - Sediments deposited by running water or streams and rivers. It may occur on terraces well above present streams or in the normally flooded bottom land of existing streams.

**ALTERED PEDOLOGICAL FEATURES** - Recognizable or distinct pedological units which differ from the undisturbed features, such as by the addition of chemical contaminants. See pedological features.

**AMENDMENT** - Any material such as lime or synthetic conditioners that is worked into the soil to make it more productive (usually materials other than fertilizers).

**AMPHOTERISM** - The ability to act as either an acid or base.

**ANAEROBIC** - (i) The absence of molecular oxygen. (ii) Growing in the absence of molecular oxygen (such as anaerobic bacteria). (iii) Occurring in the absence of molecular oxygen (as a biochemical process).

**ANALYTICAL PARAMETERS, Superfund** - Constituents and levels of detection, usually chemical, required for sample analysis. Parameters also include field measurements (e.g., soil permeability, particle size analysis), and Contract Laboratory Program (CLP) Special Analytical Services (SAS) components. See Contract Laboratory Program.

**ANION EXCHANGE CAPACITY** - The total exchangeable anions (non-metallic ions, acid radicals and hydroxyl ions) that a soil can absorb, expressed in milliequivalents per 100 grams or per gram of soil. See ion exchange.

**ANISOTROPIC** - A condition of a medium whose physical properties vary in different directions. See anisotropic soil. Antonym, isotropic.

**ANISOTROPIC SOIL** - A soil with hydraulic conductivity in different directions. Compare with isotropic soil.

**AQUATIC PLANTS** - Vegetation whose growth medium is primarily water, although they may be rooted in soil. They include primarily free-floating plants, all surface and submerged rooted plants, swamp and marsh vegetation having roots periodically or primarily submerged in water.

**AQUIFER** - An underground geological formation, or group of formations, containing usable amounts of ground water that can supply wells and springs; a body of rock or soil sufficiently permeable to conduct ground water and to yield significant quantities of water to wells or springs.

**AREA** - A general, wide term used for any portion of the earth's surface. It includes positional location and the environmental content, e.g., site area. See site.

**ARGILLACEOUS** - Rocks or sediments largely composed of clay minerals or clay-sized particles.

**ARTHROPOD** - Invertebrate animals, such as insects, arachnids, and crustaceans, that have a jointed body and limbs; any of the phylum Arthropoda. See microfauna.

**ATTENUATION** - The process by which a compound is reduced in concentration over time, through absorption, degradation, dilution, and/or transformation.

**AITERBERG LIMITS** - The collective designation of seven so-called limits of consistency of fine-grained soils. See consistency.

**AVAILABLE WATER** - The portion of water in a soil that can be absorbed by plant roots. It is the amount of water released between in situ field capacity and the permanent wilting point.

**BACKGROUND SOIL PROPERTY** - The property or characteristic of a soil prior to the addition of substances or materials that alters its natural (indigenous) state or conditions.

**BACTERIA** - (Singular: bacterium) Microscopic living organisms which can aid in pollution control by consuming or breaking down organic matter in sewage or by similarly acting on oil spills or other water pollutants. Bacteria in soil, water or air can also cause human, animal and plant health problems.

**BAROMETRIC PRESSURE** - Atmospheric pressure measured with a mercury or aneroid (no fluid) barometer.

**BAROTAXIS** - Response by locomotion of an organism (or part) in response to barometric stimulus.

**BASAL AREA** - (i) The area of the cross section of a tree at height 1.4 m above the ground, usually expressed as the summation of the basal area of the trees in a forest in square meters per hectare. (ii) The surface of the soil actually covered or occupied by a plant, especially the basal part, as compared to the full spread of the herbage; in grassland ecology often measured at 2 cm above the ground surface. See ground cover.

**BASALT** - See granular rock structure.

**BASE** - A substance that in aqueous solution increases the hydroxide ion concentration.

**BASE CATIONS** - Soil exchangeable cations: calcium, magnesium, potassium and sodium.

**BASE SATURATION** - The relative degree to which soils have metallic cations absorbed. The proportion of the cation-exchange capacity that is saturated with metallic cations. See great soil group.

**BASIC ANHYDRIDE (BASIC OXIDE)** - A metal oxide that forms a base with water. See oxides.

**BATHTUB EFFECT** - An overflow effect commonly seen in landfills located in impermeable clay soils where infiltration of precipitation through waste and cover materials exceeds the capacity of the soil to absorb the normal rainfall. Springs of leachate may appear around the site perimeter.

**BEDROCK** - (i) Any solid rock exposed at the earth's surface or overlain by unconsolidated material. (ii) The solid rock on which alluvial gold rests.

**BERM** - A narrow bench or dike-like barrier of earth commonly built to contain spills or liquid waste.

**BICARBONATE** - A salt containing a metal and the radical hydrogen carbonate ( $\text{HCO}_3^-$ ), e.g.,  $\text{NaHCO}_3$ .

**BIODEGRADABLE** - The ability to break down or decompose rapidly under natural conditions and processes.

**BIODEGRADATION** - Decomposition of substances or materials into more elementary compounds by the action of microorganisms, such as bacteria or fungi.

**BIOLOGICAL WASTE** - Any waste derived or originating from living organisms: microorganisms, meso- and macro animals, plants, and also humans.

**BIOMASS** - All of the living material in a given area; often refers to vegetation. Also called "biota."

**BIOME** - A large, easily recognized community unit formed by the interaction of regional climates with regional biota and substrates. In a given biome the life form of the climatic climax vegetation is uniform. Thus, the climax vegetation of the grassland biome is grass, although the dominant species of grass may vary in different parts of the biome.

**BIOTA** - All of the living organisms, macro, meso or micro, that exist in a given area or environment.

**BIOTIC COMMUNITY** - A naturally occurring assemblage of plants and animals that live in the same environment and are mutually sustaining and inter-dependent.

**BLOCK (BLOCKY)** - (i) An angular fragment over 256 mm in diameter showing little or no modification in form due to transportation; similar in size to a boulder.

**BLUE-GREEN ALGAE** - See cyanobacteria.

**BORING LOGS** - Engineering and geologic descriptions of exploration drill holes commonly utilized during the design and planning phases of construction projects. Also may provide useful descriptions relevant to waste disposal sites.

**BORROW PIT** - An excavated area where earth materials (not rock) have been removed to use for fill or construction elsewhere. Some borrow pits may be subsequently used as dumps, landfills or waste disposal sites.

**BULK AREA** - The total area, including solid particles and pores, of a cross-section through an arbitrary quantity of soil; the area counterpart of bulk volume.

**BULK DENSITY** - The ratio of the mass of dry solids to the bulk volume of the soil.

B.D. = gms of soil dried to 105°C/cc of soil volume obtained in the field.

**BULK WASTE** - Large items of solid or oversize waste that preclude or that complicate handling by normal solid waste collection, processing or disposal methods.

**BURIAL GROUND (GRAVEYARD)** - A disposal site for radioactive waste materials that uses earth or water as a shield.

**BURIED SOILS** - A soil is considered to be a buried soil if there is a surface mantle of new material such as alluvial, loessal, or other depositional surface mantle that is 50 cm or more thick or if there is a surface mantle between 30 and 50 cm thick and the thickness of the mantle is at least half that of the named diagnostic horizons that are preserved in the buried soil. Buried soils may be encountered in the natural environment as well as at disturbed sites.

**CALICHE** - (i) A zone near the surface, more or less cemented by secondary carbonates of Ca or Mg precipitated from the soil solution. It may occur as a soft thin soil horizon, as a hard thick bed, or as a

surface layer exposed by erosion. (ii) Alluvium cemented with  $\text{NaNO}_3$ ,  $\text{NaCl}$ , and/or other soluble salts in the nitrate deposits of Chile and Peru.

**CALIFORNIA LIST OF WASTES** - RCRA hazardous waste that contains cyanides, RCRA metals, or PCBs, or waste that is corrosive (i.e., pH of 2 or less); and any liquid or nonliquid hazardous waste containing halogenated organic compounds (HOCs). See RCRA, halogenated wastes, and PCBs.

**CAP** - A layer of clay or other highly impermeable material installed over the top of a closed landfill to prevent entry of rainwater and minimize production of leachate.

**CAPILLARY FRINGE** - A zone in the soil just above the plane of zero gauge pressure that remains saturated or almost saturated with water. The extent can be inferred from the retentivity curve and depends upon the size-distribution of pores.

**CARBONATE** - A salt or ester of carbonic acid; a compound containing the radical carbonate ( $\text{CO}_3^{2-}$ ).

**CATALYSIS** - A modification, especially an increase, in the rate of a chemical reaction induced by material unchanged chemically at the end of the reaction.

**CATION EXCHANGE CAPACITY (CEC)** - The sum total of exchangeable cations that a soil can adsorb, expressed in milliequivalents per 100 grams or per gram of soil. Usually determined by ammonium acetate at pH 7. See ion exchange.

**CERCLA** - Comprehensive Environmental Response Compensation and Liability Information System Act of 1980. CERCLA focuses on inactive or uncontrolled sites. The major concern of CERCLA is cleanup of hazardous substances releases at uncontrolled or abandoned hazardous waste sites. Compare with RCRA. See hazardous substance, hazardous waste site, and Superfund.

**CFR (40 CFR)** - Code of Federal Regulations dealing with protection of the environment.

**CHANGES OF STATE** - Interconversions between the solid, liquid and gaseous states.

**CHARACTERISTIC WASTE** - A solid waste that is a hazardous waste because it exhibits one or more of the following hazardous characteristics: ignitability, corrosivity, reactivity, or toxicity. See also toxicity characteristic rule and toxicity characteristic leaching procedure.

**CHELATES** - Certain organic chemicals, known as chelating agents, form ring compounds in which a metal is held between two or more atoms strongly enough to diminish the rate at which it becomes fixed by soil, thereby making it more available for plant uptake. See organic complexation, inorganic complexation.



**CHELATING AGENT** - An agent, such as a humus fraction, that has more than one atom and that may be bonded to a central metal ion at one time to form a ring structure. Chelating agents can be common water or soil pollutants.

**CHELATION** - The retention of a metallic ion by two atoms of a single organic molecule.

**CHEMICAL LANDFILL** - A landfill used for disposal of chemicals. See landfill.

**CHEMICAL PRECIPITATION** - For RCRA corrective action, solubilized metals are separated from water by precipitating them with insoluble salts.

**CHEMICAL SPECIATION** - The form in which an element is present, e.g., a species of aluminum in the trivalent form,  $Al^{3+}$ .

**CHEMICAL WASTE** - Any organic or inorganic waste of a particular molecular identity generated by various industrial manufacturing processes or other processes.

**CLASSIFIED WASTE** - Waste material having a security classification in accordance with regulation 50 U.S.C. 401 and Executive Order 11652.

**CLAY** - (i) A soil separate consisting of particles < 0.002 mm in equivalent diameter. (ii) A textural class. See soil texture and soil separates.

**CLAY MINERAL** - (i) Any crystalline inorganic substance of clay size (i.e., **2  $\mu$ m equivalent spherical diameter**). (ii) Any phyllosilicate of clay size. See phyllosilicate mineral. (iii) Naturally occurring, inorganic, crystalline phyllosilicate (sheet layer silicate mineral) materials found in soils and other earthy deposits; not limited to particle size of 0.002 mm diameter or less.

**CLAY PARTICLES** - A clay-sized particle consisting of both mineral and organic constituents. See clay.

**CLAYPAN** - A dense, compact layer in the subsoil having a much higher clay content than the overlying material, from which it is separated by a sharply defined boundary; formed by downward movement of clay or by synthesis of clay in place during soil formation. Claypans are usually hard when dry, and plastic and sticky when wet.

**CLEAN FILL** - Inert materials, especially soils or rock that are commonly used to fill depressions prior to construction of large buildings, parking lots or housing developments. May also be used to cover deposited wastes.

**CLEANUP** - Actions taken to deal with a release or threat of release of a hazardous substance that could affect humans and/or the environment. The term "cleanup" is sometimes used interchangeably with the terms remedial action, removal action, response action, or corrective action.

**CLIMATE AND WEATHER** - Climate: the average course or condition of the weather for the site and region over a period of years as exhibited by temperature, meteoric precipitation, and wind. Weather: the state of the atmosphere at the site and region during the time of study with respect to heat or cold, wetness or dryness, calm or storms, clearness or cloudiness, and barometric pressure.

**CLIMATE TYPES** - The climate of an area designated as the location in which it is found, e.g., continental.

**CLIMATIC REGIME** - A province or region of the earth's surface characterized by an essentially homogeneous climate.

**CLOD** - A soil mass or lump produced artificially usually when a wet soil is cultivated or otherwise manipulated.

**CLP** - See Contract Laboratory Program.

**COARSE-TEXTURED SOIL** - A description of a class of soil texture which is characterized by sands, loamy sands, and sandy loams (except for very fine sandy loam).

**CODE OF FEDERAL REGULATIONS** - See CFR.

**COLLOID** - (i) Substances made up of very fine particles larger than most molecules. Soils (and plants) contain a large amount of solid material in the colloidal state. The upper size limit is 0.1 mm. (ii) A substance that, when apparently dissolved in water, diffuses not at all or very slowly through a membrane and usually has little effect on freezing point, boiling point, or osmotic pressure of the solution; a substance in a state of fine subdivision, with particles ranging from  $10^{-5}$  to  $10^{-7}$  cm in diameter. See soil colloids.

**COLOR, CHROMA** - One of the three variables of color. The relative purity, strength, or saturation of a color; directly related to the dominance of the determining wavelength of the light and inversely related to grayness. See Munsell Color System.

**COLOR, HUE** - One of the three variables of color. It is attributed to light of certain wavelengths and changes with the wavelengths. See Munsell Color System.

**COLOR** - The phenomena of light or visual perception of the soil's physical appearance in terms of hue, lightness, and saturation; measurement is by reference to standard color charts (e.g., Munsell color system for hue, value, and chroma) to make up a specific color notation.

**COLOR, VALUE** - One of the three variables of color. The relative lightness or intensity of color. Approximately, a function of the square root of the total amount of light. See Munsell Color System.

**COMBUSTIBLE WASTE** - Any waste materials that are burnable, e.g., wood, paper, cloth, certain plant parts, food, plastics, paints, solvents, and fuels.

**COMETABOLISM (COOXIDATION)** - The metabolism by microorganisms of a compound that the cell is unable to use as a source of energy or an essential nutrient.

**COMPACTION** - (i) The squeezing together of soil particles under mechanical load by rolling, tamping, or vibration to expel air, usually by the weight of farm, construction, and other equipment; vehicles; and animal and foot traffic. (ii) Increasing the soil bulk density and concomitantly decreasing the soil porosity by application of mechanical forces to the soil.

**COMPLEX** - A compound formed between a metal atom or ion with acceptance of one or more electron pairs, and ions or neutral molecules that donate electron pairs,

**COMPLEXATION** - The formation of complex ions or compounds. Also see chelation.

**COMPOST** - A mixture of garbage and degradable trash with soil in which certain bacteria in the soil break down the garbage and trash into organic fertilizer.

**COMPRESSIBILITY** - The property of a soil pertaining to its susceptibility to decrease in bulk volume when subjected to a load. Not to be confused with compaction.

**CONCRETION** - A small module or lump of relatively concentrated compound such as calcium carbonate, iron oxide, etc. found in many soils, and varying in shape, hardness, size, and color.

**CONSISTENCY** - The resistance of the soil material to deformation or rupture; the degree of cohesion of the soil mass, and as described at various soil moisture contents. Also see Atterberg limits, liquid limit, plastic limit.

**CONTAINER** - Any portable device in which a material is stored, transported, disposed of, or otherwise handled.

**CONTAINMENT** - Capping, slurry walls, etc., around waste or contaminated soils to prevent surface and ground water migration and contaminant transport.

**CONTAMINANT** - Any physical, chemical, biological, or radiological substance or matter that has an adverse affect on air, water, soil, or biota.

**CONTAMINANT DETECTABLE CONCENTRATION** - Any concentration of a contaminant in a medium, such as soil or water, that is greater than or equal to the particular method detection limit.

**CONTAMINANT DISPERSION** - Spread of a contaminant in a system, such as soil, one phase of which is in the form of finely divided particles, e.g., a contaminant in soil solution, distributed throughout a bulk substance, e.g., a metal dispersed in soil solid particles.

**CONTAMINANT MIGRATION** - The movement of contaminants on or off-site due to soil permeability, erodibility, depth to ground water, flooding potential, landform and other factors.

**CONTAMINANT MIGRATION POTENTIAL** - The potential for a contaminant to migrate off-site. Factors for high potential include (1) slope with relatively impermeable bedrock, (2) karst topography, (3) little topographic relief with ground water at or very near the surface, and (4) a shallow soil depth (profile), fractured bedrock and high ground water table.

**CONTAMINANT RETARDATION** - The hinderance, delay, or slowing of progress of contaminant migration through soil and to ground water.

**CONTINGENCY PLAN** - A document setting out an organized, planned, or coordinated course of action to be followed in case of a fire, explosion, or release of hazardous waste constituents which could threaten human health or the environment.

**CONTRACT LABORATORY PROGRAM (CLP), Superfund** - Laboratories under license to EPA, which analyze samples taken from wastes, soil, air and water or carry out research projects.

**CONTRASTING SOIL** - A soil that does not share diagnostic criteria and does not have or perform similar to the soil with which it is being compared.

**COPROGENOUS EARTH** - (i) Sediments or soil derived from or containing excrement, dung or fecal materials. (ii) Sedimentary peat. See limnic materials.

**CORROSION POTENTIAL** - See corrosivity.

**CORROSIVE** - A chemical agent that reacts with the surface of a material, causing it to deteriorate or wear away.

**CORROSIVE WASTE** - Waste that has the ability to corrode the standard materials of a container or have the ability to dissolve toxic contaminants. Aqueous wastes  $\leq$  pH 2 or  $\geq$  pH 12 are considered corrosive.

**CORROSIVITY (CORROSION POTENTIAL)** - The ability of the soil to wear away and degrade metal materials with time, usually by chemical and microbial action, and as determined by soil characteristics.

**COVALENT BONDING** - Bonding based upon electron-pair sharing; the attraction between two atoms that share electrons. See semiconducting elements.

**COVER, VEGETATION** - The area of ground covered by the sum total of plants in an area. See ground cover.

**CRITERIA** - Descriptive factors taken into account by EPA in setting standards for various pollutants. These factors are used to determine limits on allowable concentration levels, and to limit the number of violations per year. When issued by EPA, the criteria provide guidance to the states on how to establish their standards.

**CRITICAL DEPTH** - The boundary limit of the zone of discernible soil, microbial activity, or depth to ground water.

**CROSS CONTAMINATION, Superfund** - The transfer of contaminants from their known or suspected location into a noncontaminated area; a term usually applied to sampling activities. See sampling activities.

**CRUMB** - (i) Very porous granular structure in soils; a porous aggregate of soil particles. (ii) In agriculture, a soft, rounded ped from 1 to 5 mm in diameter. See ped.

**CRUST** - See soil crust and desert crust.

**CULTURE** - A population of microorganisms cultivated in an artificial growth media. A pure culture is grown from a single cell; a mixed culture consists of two or more microorganisms growing together.

**CULTURE MEDIUM** - A mixture of nutrient substances in which microorganisms are grown.

**CYANIDE** - Any of a group of compounds containing the carbon-nitrogen group and derived from hydrogen cyanide. Commonly included by EPA with the priority list of inorganics, including heavy metals, as a hazardous waste contaminant, and analyzed by CLP laboratories.

**CYANOBACTERIA** - Bacteria, also called "blue-green" algae, which are generally photosynthetic, pigmented (phycobilin), unicellular or multicellular, microscopic, or forming discernible masses in or upon soil, water, and other substrates, e.g., oil wastes, sewage, bones, shells, wood, etc. See microflora, algae, and bacteria.

**DARCY HYDRAULIC CONDUCTIVITY** - See hydraulic conductivity, intrinsic permeability.

**DARCY VELOCITY** - A standard unit of permeability, equivalent to the passage of one cubic centimeter of fluid of one centipoise viscosity flowing in one second under a pressure differential of one atmosphere through a porous medium having an area of cross section of one square centimeter and a length of one centimeter. See soil permeability.

**DARCY'S EQUATION** - In a porous medium, such as soil, the gross velocity  $v$  of water is equal to the hydraulic gradient  $i$  times the hydraulic conductivity  $K$ . See hydraulic conductivity and hydraulic gradient.

**DARCY'S LAW** - (i) A law describing the rate of flow of water through porous media. (Named for Henry Darcy of Paris, who formulated it in 1856 from extensive work on the flow of water through sand filter beds.) As formulated by Darcy the law is

$$Q = KS(H + e)/e$$

where  $Q$  is the volume of water passed in unit time,  $S$  is the area of the bed,  $e$  is the thickness of the bed,  $H$  is the depth of water on top of the bed, and  $K$  is the coefficient dependent on the nature of the sand, and for cases when the pressure under the filter is equal to the weight of the atmosphere. (ii) Generalization for three dimensions: The rate of viscous flow of water in isotropic porous media is proportional to, and in the direction of, the hydraulic gradient. (iii) Generalization for other fluids: The rate of viscous flow of homogenous fluids through isotropic porous media is proportional to, and in the direction of, the driving force. See hydraulic gradient, hydraulic conductivity, and isotropic soil.

**DECOMPOSITION** - The breakdown of matter by bacteria and fungi into similar substances. It changes the chemical makeup and physical appearance of materials.

**DEEP WELL INJECTION STORAGE** - The injection of fluids, such as for waste disposal, into wells beneath shallow impermeable strata at depths exceeding 6.7 m (22 feet). See injection well and disposal.

**DEGRADATION RATE (CHEMICAL PERSISTENCY)** - The rate at which a chemical is broken down in the environment by hydrolysis, photodegradation, or soil metabolism; the length of time that a parent chemical persists in the environment.

**DEGRADATION** - The process whereby a compound is transformed into simpler compounds, although products more complex than the starting material may be formed. Also see soil degradation.

**DELINEATION** - A portion of a landscape shown by a closed boundary on a soil map that defines the area, shape, and location of one or more component soils plus inclusions, and/or miscellaneous area. See soil map unit.

**DELISTING** - Exclusion (or petitioning for exclusion) of a solid waste from the definition of "hazardous waste," even though so listed under RCFW.

**DEPOSIT** - Material left in a new position by a natural transporting agent such as water, ice, or gravity, or by the activity of man. May also include materials resulting from dumping of wastes, chemicals and spills.

**DEPTH TO GROUND WATER** - Depth in feet or meters from the soil surface to the upper surface of ground water (the water table), or that level in the ground where the water is at atmospheric pressure.

**DESALINIZATION** - The process of leaching the excess soluble salts from a soil.

**DESERT CRUST** - A hard layer, containing calcium carbonate, gypsum, or other binding material, exposed at the surface in desert regions. See soil crust.

**DESORPTION** - The displacement of ions from the solid phase of the soil solution by a displacing ion.

**DIAGNOSTIC SOIL HORIZONS** - In soil survey, these are quantitatively defined features used to differentiate between taxa in the U.S. system of soil taxonomy. See genetic soil horizons, soil master horizons and layers.

**DIATOMS** - Algae having siliceous cell walls that persist as a skeleton after death. Any of the microscopic unicellular or colonial algae constituting the class Bacillariaceae. They are abundant in fresh and salt waters and wet soils. Their remains are widely distributed in soils. See microflora.

**DIFFERENTIAL WATER CAPACITY** - The absolute value of the rate of change of water content with soil water pressure. The water capacity at a given water content will depend on the particular desorption or adsorption curve employed. Distinction should be made between volumetric and specific water capacity. See soil water (moisture).

**DIFFUSION** - See soil nutrient diffusion.

**DILUTION** - Thinning down or weakening of a compound by mixing with water or other solvents. Contaminants introduced into soil may become spatially diluted over time.

**DIRECT COUNTS** - In soil microbiology, a method of estimating the total number of microorganisms in a given mass of soil by direct microscopic examination.

**DIRECTIONAL HYDRAULIC CONDUCTIVITY** - Two-directional hydraulic conductivity (vertical and horizontal). See anisotropy and anisotropic soil.

**DIRT** - (i) A commonly used term in construction, earth moving and engineering referring to soil and soil-like materials, including contaminated materials and debris of soil-size dimensions. (ii) Loose packed soil or sand. (iii) Alluvial earth in placer mining. (iv) Slate and waste from coal mines. (v) Fill material with soil-like quantities or dimension. See spoil.

**DISPERSED SOIL** - A soil which has some of its smaller particles dispersed or suspended in a liquid, e.g., the clay particles may be dispersed in water. A dispersed soil usually runs together and becomes plastic when wet; includes characteristics of low permeability, high bulk density, and forms hard lumps or clods upon drying.

**DISPOSAL** - Final placement or destruction of the following: toxic, radioactive, or other waste surplus or banned pesticides or other chemicals, polluted soils, and drums containing hazardous materials

from removal actions or accidental releases. Disposal may be accomplished through use of approved secure landfills, surface impoundments, land farming, deep well injection, ocean dumping, or incineration.

**DISSOLUTION** - The separation into component parts through the process of dissolving, usually in a solution.

**DISTANCE TO RECEPTOR** - The distance from the contaminated medium (soil), to a user in the direction of ground water flow.

**DISTURBED SOILS** - Any soil material that has been truncated or manipulated to the extent that its principle pedogenic characteristics have been severely altered or can no longer be recognized.

**DNA PROBE** - A segment of DNA to detect complimentary strands of DNA. Used to confirm presence of microorganisms, abundance of microorganisms, or a species of microorganisms.

**DUMPS** - (i) Areas of smooth or uneven accumulations or piles of waste rock or general refuse. In an agricultural sense, without major reclamation the areas are incapable of supporting plants. (ii) A site used to dispose of solid wastes without environmental controls.

**DURIPAN** - A mineral soil horizon that is cemented by silica, usually opal or microcrystalline forms of silica, to the point that air-dry fragments will not slake in water or HCl. A duripan may also have accessory cement such as iron oxide or calcium carbonate. Also, see iron-pan, claypan, and caliche.

**ECOLOGICAL AMPLITUDE** - The range of one or more environmental conditions in which an organism or a process can function. Within this range, e.g., optimum conditions are that range most favorable for the organism/process. Compare tolerance, resistance.

**ECOLOGICAL IMPACT** - The effect that a man-made or natural activity has on living organisms and their non-living (abiotic) environment.

**ECOSYSTEM** - A community of organisms and the environment in which they live.

**Eh** - See redox potential.

**ELECTROCHEMICAL SENSOR** - A device that senses either the absolute value of a quality or change (e.g., pH) and converts this data into an input signal for an information-gathering system. See ion selective electrode.

**ELECTROPLATING** - Electrodeposition of a metal or alloy from a suitable electrolyte (current conducting) solution. Electroplating solutions can be important soil metal contaminants.



**ELECTRICAL CONDUCTIVITY** - The ratio of the electrical current density to the electric field in the soil; expressed in the reciprocal value of its resistivity in mhos/cm, mmhos/cm or siemens/meter of soil extract or paste and generally referable to the salt/solute content of the soil as determined at a given moisture content and temperature.

**ELEMENTAL ANALYSIS** - The total amount of a chemical element, including metals, determined by various wet and dry methods and analytical instruments. See soil chemical properties.

**ENDANGERED SPECIES** - Animals, birds, fish, plants, or other living organisms threatened with extinction by man-made or natural changes in their environment. Requirements for declaring a species endangered are contained in the Endangered Species Act.

**ENGINEERED SOILS** - Soils used for engineering purposes and rated in terms of suitability, limitations, and restrictive features.

**ENVIRONMENT** - The sum of all external conditions affecting the life, development, and survival of an organism.

**ENVIRONMENTAL RESPONSE TEAM** - EPA experts currently located in Edison, NJ, and Cincinnati, OH, who can provide around-the-clock technical assistance to EPA regional offices and states during all types of emergencies involving hazardous waste sites and spills of hazardous substances.

**ENVIRONMENTAL SAMPLES, Superfund** - Samples with low concentrations of hazardous contaminants. See sample, low concentration, Superfund.

**EPA HAZARDOUS WASTE NUMBER** - A number assigned by EPA to waste that is hazardous by definition; to each hazardous waste listed in 40 CFR 261 Subpart D from specific and nonspecific sources identified by EPA (F, K, P, U); and to each characteristic waste identified in 40 CFR 261 Subpart C, including wastes with ignitable (D001), reactive (D002), corrosive (D003), and EP toxic (D004-D017) characteristics.

**EPIPEDON** - A diagnostic soil horizon that forms at the surface and has been either appreciably darkened by organic matter or eluviated or, as a minimum, rock structure has been destroyed. There can be only one epipedon formed in the mineral horizon(s) of a soil, but it may be overlain with organic materials. There are seven diagnostic epipedons. For details, see USDA Soil Survey Staff, Keys to Soil Taxonomy, Tech. Monogr. No. 19, 1990 or other soil taxonomic reference.

**ERODIBILITY** - The vulnerability or degree of susceptibility of soil to erosion processes.

**EROSION** - (i) The wearing away of the land surface by running water, wind, ice, or other geological agents, including such processes as gravitational creep. (ii) Detachment and movement of soil or rock by water, wind, ice or gravity. For terms to describe different types of water and wind erosion, see Soil Science Society of America, Glossary of Soil Science Terms, 1987.

**EROSION CLASSES** - A grouping of erosion conditions based on the degree of erosion or on characteristic patterns. (Applied to accelerated erosion; not to normal, natural, or geological erosion.) Four erosion classes are recognized for water erosion and three for wind erosion. Specific definitions for each vary somewhat from one climatic zone, or major soil group, to another. For details see USDA Soil Survey Staff, SCS, 1981. Soil Survey Manual. U.S. Dep. Agric. Handbook 18, or other soil survey manual.

**ESSENTIAL ELEMENTS** - Those elements which must be present in the soil for a plant to grow normally. Both macro and micronutrients are necessary. See macro and micronutrients.

**EVAPORATION** - The process whereby a liquid changes its state and becomes a vapor. In agriculture, it is the diffusion of water as a vapor from the surface of plants or soil to the atmosphere.

**EVAPOTRANSPIRATION** - The movement of liquid (usually water) from plant surfaces, including soil algal- and lichen-crusts, by a combination of evaporation and transpiration; the loss of water from the soil both by evaporation and by transpiration from the plants growing in the soil.

**EXCEEDANCE** - Violation of environmental protection standards by exceeding allowable limits or concentration levels.

**EXCHANGEABLE SOIL IONS** - Those ions held by a soil complex which may be readily replaced by other ions. Both anions and cations are exchangeable. See anion and cation exchange capacity.

**EXPERT SYSTEM** - (i) Generally considered to be a branch of artificial intelligence; with its knowledge-based system, can function as an "expert" to make higher-level decision based on varying performance levels. (ii) A "man and machine" system with specialized problem-solving expertise. See knowledge base. Also see the following references: Coulson et al., 1987; Fang et al., 1990; Olivero and Bottrell, 1990; and Schmuller, 1990.

**EXPOSURE** - (i) The amount of radiation or pollutant present in an environment which represents a potential health threat to the living organisms in that environment; (ii) Human contact with a physical, chemical or biological agent through dermal absorption, inhalation or ingestion.

**EXTREMELY HAZARDOUS SUBSTANCE** - Any of more than 400 chemicals, subject to revision, identified by the EPA, or on the basis of toxicity, and listed under SARA Title III. The list is subject to revision. Also see SARA.

**FACILITY** - All contiguous land and structure, other appurtenances, and improvements on the land used for treating, storing, or disposing of hazardous waste. A facility may consist of several treatment, storage, or disposal operational units e.g., one or more landfills, surface impoundments, or combinations of them.

**FACULTATIVE MICROORGANISMS** - Any microorganisms that are able to carry out both options of a mutually exclusive process e.g., aerobic and anaerobic metabolism. May also be used in reference to other processes, such as photosynthesis.

**FERMENTATION** - Chemical reactions accompanied by living microbes that are supplied with nutrients and other critical conditions such as heat, pressure, and light that are specific to the reaction at hand.

**FERTILE SOIL** - A soil having the ability to supply nutrients essential to plant growth. See macronutrients and micronutrients. Compare with productive soil.

**FERTILITY POTENTIAL** - The ability or status of the soil to supply nutrients necessary for plant growth; usually determined by soil tests (i.e., chemical, physical or biological procedures that estimate a property of the soil pertinent to the suitability of the soil to support plant growth).

**FERTILIZER** - Any organic or inorganic material of natural or synthetic origin (other than liming materials) that is added to a soil to supply one or more elements essential to the growth of plants.

**FIBRIC SOIL MATERIAL** - One of three kinds of basic organic soil materials. A fiber is a fragment or piece of plant tissue, excluding live roots, that is large enough to be retained on a 100-mesh sieve (openings 0.15 mm in diameter) and that retains recognizable cellular structure of the plant from which it came. Also, see hemic and sapric soil materials.

**FIELD CAPACITY** - The field water capacity or in situ water content on a mass or volume basis which remains in a soil 2 or 3 days after it has been wetted with water and after free drainage is negligible. See available water. (Also, may be applied to liquid chemicals other than water to reach field capacity.)

**FIELD CROPS** - Vegetation commercially cultivated and produced for the primary purpose of providing food and clothing for humans or food for domestic livestock.

**FIELD INVESTIGATION TEAM (FIT), Superfund** - A team composed of two and up to six or more members needed in a hazardous substance site investigation. The level of site operations determines the minimum number of team members. Primary function of the FIT is to conduct field work needed to gather information according to the approved work plan, to conduct remedial response activities, and to meet the goals of the investigation of hazardous waste disposal sites.

**FIELD-SATURATED HYDRAULIC CONDUCTIVITY** - Saturated hydraulic conductivity of a porous medium, e.g., soil, containing entrapped air. See hydraulic conductivity, saturated.

**FINE-TEXTURED SOIL** - A description of a class of soil texture which is characterized by the dominant presence of the smaller soil particles, clay or silt. See clay and silt.

**FLOCCULATION** - The coagulation of dispersed particles in a medium, e.g., in a clay suspension the colloids are dispersed (present as separate particles and not as aggregates or group). See dispersed soil.

**FOLIAR ANALYSIS** - The analysis of a prepared sample of plant material into its content of various elements. This examination may be preferable to an analysis of the soil in which the plant is growing. Foliar analysis provides an estimate of the quantity available of the elements the plant is able to extract from the soil, rather than the data supplied by a soil sample analysis, which estimates which quantities of elements the soil contains.

**FOLIAR DIAGNOSIS** - An estimation of the mineral contents of plants by means of chemical analysis tests carried out on the whole or part of the plant. By this method an indication is obtained of which elements the plant is able to extract from the soil in which it grows. Any excess or deficiency (including toxicity) in the plant may be diagnosed.

**FORBS** - An herbaceous plant that is not a grass or grasslike; for example, sunflowers. Also see herbs, plant type, ground cover.

**FLUX DENSITY** - The volume of water passing through a unit cross-sectioned area (perpendicular to the flow direction) per unit time (in a soil). See hydraulic conductivity.

**FRAGIPAN** - A natural subsurface horizon with high bulk density and/or high mechanical strength relative to the solum above, seemingly cemented when dry, but when moist showing a moderate to weak brittleness. The layer is low in organic matter, mottled, slowly or very slowly permeable to water, considered to be root restricting, and usually shows occasional or frequent bleached cracks forming polygons. It may be found in profiles of either cultivated or virgin soils but not in calcareous material.

**FREE LIQUIDS** - Liquids which readily separate from the solid portion of a waste under ambient temperature and pressure.

**FROZEN SOIL** - A soil with a horizon or layer containing permanent ice.

**FUNGI** - (Singular: Fungus) Molds, mildews, yeasts, mushrooms, and puffballs, a group of organisms that lack chlorophyll (i.e., are not photosynthetic) and are usually non-mobil, filamentous, and multicellular. Some grow in the ground, others attach themselves to decaying trees and other plants, getting their nutrition from decomposing organic matter. Some cause disease, others stabilize sewage and break down solid wastes in composting.

**GENERATOR** - A facility or mobile source that emits pollutants into the air and/or releases hazardous wastes into water or soil.

**GENETIC SOIL HORIZONS** - In soil survey, genetic horizons are not the equivalent of the diagnostic horizons of the U.S. Soil Taxonomy. Designations of genetic horizons express a qualitative judgment about the vector of changes that are believed to have taken place.

**GEOLOGICAL AND GEOPHYSICAL LOGGING, Super-fund** - A detailed systematic and sequential record of the progress of drilling a well or borehold, or of excavating pits and trenches at a hazardous waste site. The record of geological logging is kept on printed log forms and may include notes on the following:

soil and rock classifications and descriptions, outcrop descriptions, depths and thicknesses of the earth materials penetrated, groundwater conditions, origin and geologic structures, drilling progress, borehold geophysical logging, sampling, type of equipment used, unusual or significant conditions, and date of drilling location of boreholes, etc.

See US EPA, 1987, A Compendium of Superfund Field Operations Methods, EPA/540/P-87/001, for additional details.

**GEOLOGICAL RECONNAISSANCE STUDY, Super-fund** - A general, exploratory examination or survey of the main features (or certain specific features) of a region, usually conducted as preliminary to a more detailed survey, and to identify the major geological or physical features at or near the hazardous waste site. Geological reconnaissance studies are conducted early in project site investigations as part of the site characterization process. See US EPA, 1987, A Compendium of Superfund Field Operations Methods, EPA/540/P-87/001, for further details.

**GEOLOGY** - (i) Scientific study of the origin, history and structure of the earth. (ii) The structure of a specific geologic region.

**GLEYED SOIL** - A soil with horizons in which water-logging and the lack of oxygen have resulted in materials (mottles) of a relatively neutral gray color. See strong gleyed soil.

**GRANITE** - See granular rock structures.

**GRANULAR ROCK STRUCTURES** - Rock texture as determined by the size of the constituent grains or crystals.

**Basalt** - A fine-grained, dark-colored igneous (volcanic) rock.

**Granite** - A crystalline plutonic rock (i.e., derived from magma, naturally occurring mobile rock material) composed of alkalic feldspar and quartz.

**Limestone** - (i) A sedimentary (formed of sediment) rock composed principally of calcium carbonate, mainly as calcite. (ii) A rock containing > 80% calcium carbonate or magnesium carbonate.

**Quartzite** - (i) A granulose metamorphic rock composed mainly of quartz. (ii) Sandstone cemented by silica.

**Sandstone** - A compacted sedimentary rock composed mainly of quartz grains silicon dioxide (SiO<sub>2</sub>) similar in size to sand (0.06 - 2 mm).

**GRAVEL** - A loose or unconsolidated deposit of pebbles, cobbles (rock between 64 and 256 mm in diameter), or boulders. See soil mineral fraction.

**GREAT SOIL GROUP** - One of the categories in the system of soil classification that has been used in the United States for many years. Great soil groups place soils according to soil moisture and temperature, base saturation status, and expression of horizons. See soil classification.

**GROUND COVER** - (i) The extent, nature, kind and distribution of vegetation in a site or area. (ii) The plants or plant parts, living or dead, on the surface of the ground. Vegetative cover or herbage cover is composed of living plants; litter cover, of dead parts of plants. (iii) The area of ground covered by plants of one or more species. See basal area.

**GROUND DATA** - Supporting data collected on the ground, and information derived therefrom, as an aid to the interpretation of remotely recorded surveys, such as airborne imagery, etc. Generally, this should be performed concurrently with the airborne surveys. Data as to weather, soils, and vegetation types and conditions are typical.

**GROUND WATER** - The supply of usually fresh water found beneath the earth's surface (rock, ground or soil), usually in aquifers, which is often used for supplying wells and springs and is a major source of drinking water.

**GROUND-WATER HYDROLOGY** - The science dealing with the movement of the soil solution in what may be considered the saturated zone of the soil profile, Also see soil hydrology.

**GROUP I ELEMENTS (METALS)** - See alkali metals.

**GROUP II ELEMENTS (METALS)** - See alkaline earth metals.

**GROUP III ELEMENTS** - The boron family. All elements in this group form the +3 oxidation state. Elements include the nonmetal (metalloid) boron, and metals aluminum, gallium, indium and tellurium. Boron tends to resemble silicon in its chemical properties.

**GROUP IV ELEMENTS** - The carbon family. All elements in this group form the +4 oxidation state. They include carbon (a nonmetal), silicon and germanium (semiconductors), and the metals tin and lead. The +2 oxidation state becomes increasingly stable down the carbon family. The +2 state is most important in the chemistry of tin and lead.

**GROUP V ELEMENTS** - The nitrogen family. The elements in this group lack three electrons of a noble gas configuration. Nitrogen and phosphorus are the nonmetals. Arsenic and antimony are the semiconducting elements. Bismuth is a metal. Oxidation states of +3, -3, and +5 are common for all the elements.

**GROUP VI ELEMENTS** - The oxygen family. The elements in this group have two electrons short of noble gas configurations. Oxygen and sulfur are the nonmetallic members. Selenium and tellurium are classed as semiconducting elements. Polonium is a rare radioactive substance with similarities to both tellurium and bismuth but is mainly metallic in its behavior. By the transfer of two electrons from metallic atoms, dinegative ions are formed by the Group VI elements. Other than oxygen, the other elements are much less electronegative and have oxidation states of +4 and +6. Sulfur and selenium both form octatomic molecules. There are polyatomic anions of sulfur, selenium and tellurium.

**GROUP VII ELEMENTS** - The halogens. Nonmetals that include fluorine, chlorine, bromine, iodine and astatine. All have high electron affinities, high electronegativities and high ionization energies. they react readily to form singly charged anions (or a single covalent bond), and in such compounds have the -1 oxidation state. Also see salts.

**HABITAT** - The place where a population (e.g, human, animal, plant, microorganism) lives and its surroundings, both living and non-living.

**HALOGENATED WASTES** - Any liquid or nonliquid hazardous waste containing halogenated organic compounds. (Halogen elements include fluorine, chlorine, bromine, iodine and astatine.)

**HALOTOLERANCE** - See saline soil and salt tolerance.

**HARDPAN** - A hardened soil layer, in the lower A or in the B horizon, caused by cementation of soil particles with organic matter or with materials such as silica, sesquioxides, or calcium carbonate. The hardness does not change appreciably with changes in water content and pieces of the hard layer do not slake in water. See caliche, claypan, and duripan.

**HAZARD** - A probability that a given pollutant, such as a pesticide, will have an adverse affect on man, animals, or the environment in a given situation,

**HAZARDOUS IDENTIFICATION** - Providing information on which facilities have extremely hazardous substances, what those chemicals are, and how much there is at each facility. The process also provides information on how the chemicals are stored and whether they are used at high temperatures.

**HAZARDOUS RANKING SYSTEM (HRS)** - The principle screening tool used by EPA to evaluate risks to public health and the environment associated with abandoned or uncontrolled hazardous waste sites. The HRS generates a score based on the potential of hazardous substances spreading from the site through the air, surface water, or ground water and on other factors such as nearby population. This score is the primary factor in deciding if the site should be on the National Priorities List and, if so, what ranking it should have compared to other sites on the list.

**HAZARDOUS SAMPLES, Superfund** - Samples with medium and high concentrations of hazardous contaminants. See sample, medium concentration and high concentration, Superfund.

**HAZARDOUS SUBSTANCE** - (i) Any material that poses a threat to human health and/or the environment. Typical hazardous substances are toxic, corrosive, ignitable, explosive, or chemically reactive. (ii) Any substance named by EPA to be reported if a designated quantity of the substance is spilled in the waters of the United States or if otherwise emitted into the environment.

**HAZARDOUS WASTE** - A broad term usually used to denote by-products and waste materials from industry, commercial establishments, and institutions that pose an unreasonable risk to the environment, specified property, and human health and safety. Includes radioactive wastes. Also see solid waste toxicity.

**HAZARDOUS WASTE ADVERSE EFFECTS** - Environmental damage or destruction to site habitat, animals, plants, or human health, and contamination of media: soil, water, and air.

**HAZARDOUS WASTE CONSTITUENT** - A constituent that causes the waste to be listed as a hazardous waste under 40 CFR Part 261 Subpart D.

**HAZARDOUS WASTE DISPOSAL** - Removal or movement of hazardous wastes to landfills or impoundments. See hazardous waste site.

**HAZARDOUS WASTE DISPOSAL SITE** - See hazardous waste site.

**HAZARDOUS WASTE ENVIRONMENTAL SAMPLE** - Representative samples of waste procured according to a developed sampling strategy and plan.

**HAZARDOUS WASTE IDENTIFICATION, Superfund** - (i) A hazardous waste by source or chemical name as classified and listed by EPA, and (ii) Description of waste properties that may be harmful to human health or the environment. These hazardous properties include ignitability, corrosivity, reactivity, toxicity (determined by the extraction procedure), radioactivity, infectiousness, phytotoxicity, teratogenicity, and mutagenicity.

**HAZARDOUS WASTE IMPOUNDMENT** - See hazardous waste surface impoundment.

**HAZARDOUS WASTE LANDFILL** - A disposal facility or area in which hazardous wastes are placed directly or onto the ground.

**HAZARDOUS WASTE LEACHATE** - The liquid that forms as wastes decompose (in a landfill) and mix with meteoric precipitation (rain water) and can enter ground water.

**HAZARDOUS WASTE MANAGEMENT UNIT** - A contiguous area of land on or in which hazardous waste is placed, or the largest area in which there is significant likelihood of mixing hazardous waste constituents in the same area. A unit may be a surface impoundment, waste pile, land treatment area, landfill cell, incinerator, tank and its associated piping and underlying containment system, or container storage area. A container alone does not constitute a unit.



**HAZARDOUS WASTE PROPERTIES** - Waste properties that may be harmful to human health or the environment: ignitability, corrosivity, reactivity, toxicity (determined by EPA's extraction procedure), radioactivity, infectiousness, phytotoxicity, and mutagenicity.

**HAZARDOUS WASTE REACTIVITY** - Those wastes that may react spontaneously; may react violently with water; or could generate toxic fumes when mixed with water or exposed to basic or mild acid conditions.

**HAZARDOUS WASTE SAMPLING STRATEGY** - A strategy of sampling of waste procured according to a developed sampling strategy and plan.

**HAZARDOUS WASTE SITE** - An area of land (or conceivably, water) or a location at which hazardous materials are stored, treated, disposed of, placed, or otherwise came to be located. This includes all contiguous land, structures, other appurtenances, and improvements on the land used for treating, storing, or disposing of hazardous materials. A site may consist of several treatment, storage, or disposal facilities (e.g., impoundments, containers, buildings, or equipment).

**HAZARDOUS WASTE SITE CHARACTERIZATION** - The distinguishing qualities or peculiarities used to describe or represent a hazardous waste site.

**HAZARDOUS WASTE STORAGE** - The containment of hazardous waste, either temporarily or for a prolonged period of years, so as not to constitute disposal of the waste.

**HAZARDOUS WASTE STREAM** - A stream defined as hazardous, or one that contains substances according to 40 CFR 261, or are exhibiting one or more characteristics of hazardous waste: corrosivity, ignitability, reactivity or toxicity.

**HAZARDOUS WASTE, Superfund** - A solid waste or a combination of solid wastes, which because of its quantity, concentration, or physical, chemical or infectious characteristics may (1) cause or significantly contribute to an increase in serious irreversible, or incapacitating reversible illness; or (2) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed or, or otherwise managed.

**HAZARDOUS WASTE SURFACE IMPOUNDMENT** - A natural depression, man-made excavation or dike area used to contain hazardous liquids or hazardous waste containing free liquids. Impoundments include holding, storage, settling, and aeration ponds, pits, lagoons, and similar areas of surface confinement. See surface impoundment, pit, pond, lagoon.

**HAZARDOUS WASTE TOXICITY** - See solid waste toxicity.

**HAZARDOUS WASTE TREATMENT** - Any method, technique, or process, including neutralization, designed to change the physical, chemical, or biological character or composition of any hazardous waste so as to neutralize such waste, or so as to recover energy or material resources from the waste,

or so as to render such waste nonhazardous, or less hazardous; safer to transport, store, or dispose of; or amenable for recovery, amenable for storage, or reduced in volume.

**HAZARDS ANALYSIS** - The procedures involved in (i) identifying potential sources of release of hazardous materials from fixed facilities or transportation accidents; (ii) determining the vulnerability of a geographical area to a release of hazardous materials; and (iii) comparing hazards to determine which present greater or lesser risks to a community.

**HEAVY METAL SOIL POLLUTION** - Contamination of the soil with metals having densities > 5 gm/cc, and which do not decompose, but tend to remain in the soil indefinitely.

**HEAVY METALS** - Those metals having a density >5 gm/cc and that precipitate in acid solution by hydrogen sulfide; comprised of 38 elements, but usually 12 metals that are most commonly used and discharged by industry: cadmium, chromium, cobalt, copper, iron, mercury, manganese, molybdenum, nickel, lead, tin and zinc.

**HEAVY SOIL** - An agricultural term denoting a soil with a high clay content.

**HECTARE** - A metric unit of area, useful for describing larger areas of contamination. 1 hectare (ha) = 10,000 square meters (m<sup>2</sup>).

**HEMIC SOIL MATERIALS** - One of the three kinds of basic organic soil materials. Hemic soil materials (Gr. hemi, half; implying intermediate decomposition) are intermediate in degree of decomposition between the less decomposed fibric and more decomposed sapric materials. They have morphological features that give intermediate values for fiber content, bulk density, and water content. They are partly altered both physically and biochemically. Also, see fibric and sapric soil materials.

**HERBS** - Plants with one or more stems, which dies back to the ground each year. Also see forbs, plant type, ground cover.

**HETEROTROPHIC ORGANISMS** - Consumers such as humans and animals, and decomposers - chiefly bacteria and fungi - that are dependent on organic matter for food.

**HIGH HAZARD MATERIALS** - Those hazardous materials which are liable to burn with extreme rapidity or from which poisonous fumes or explosions are a concern in case of fire.

**HIGH-LEVEL RADIOACTIVE WASTE** - Waste primarily from spent nuclear fuels and characterized by high-level radiation which decays (loses radioactivity rapidly). The constituent elements have not been separated by processing. High-level waste must be handled by remote control behind heavy and protective shielding. It is a serious threat to anyone who comes near the wastes without shielding. Also compare with low-level radioactive waste.

**HORIZON** - See soil master horizons and layers; diagnostic and genetic horizons.

**HUMAN HEALTH AND SAFETY** - Any activity or situation that can adversely affect human health or increase the risk due to accidental exposure. Exposure includes toxic or hazardous waste sites, hazardous or toxic chemicals and gases, radiation, etc.

**HUMIDITY** - The degree of wetness of the atmosphere; the amount of water vapor in the air. See relative humidity.

**HUMIC SUBSTANCES** - The organic high molecular weight substances which have a high affinity for metals and are largely insoluble in the soil water. Compare with nonhumic substances.

**HUMUS** - (i) Total organic compounds in soil, exclusive of undecayed, partially decomposed or biomass materials. (ii) Organic layers of the forest floor.

**HYDRAULIC CONDUCTIVITY** - The rate of water movement within the soil as dependent upon soil properties, saturated and unsaturated, and hydraulic gradient at that time.

**HYDRAULIC CONDUCTIVITY (K), SATURATED** - The ratio of the flux density to the hydraulic gradient, or the slope of the flux versus gradient curve in a water-saturated medium (e.g., soil). The moving force is the gradient of a positive pressure potential. K is affected by total porosity of the soil, the distribution of pore sizes, and tortuosity. See hydraulic gradient, flux density, porosity, tortuosity, and hydraulic conductivity, unsaturated.

**HYDRAULIC CONDUCTIVITY (K), UNSATURATED** - The ratio of the flux density to the hydraulic gradient, or the slope of the flux versus gradient curve in an unsaturated medium (e.g., soil). Water in an unsaturated soil is additionally subject to a substance pressure (suction) equivalent to a negative pressure potential. See hydraulic gradient, flux density, porosity, tortuosity and hydraulic conductivity, saturated.

**HYDRAULIC CONDUCTIVITY CLASS** - The classification of hydraulic conductivity as based upon rate of water movement, e.g., in soil survey: high, moderate and low.

**HYDRAULIC GRADIENT (aquifer)** - In an aquifer, the rate of change of total head (pressure) per unit of distance of flow at a given point in a given direction.

**HYDRAULIC GRADIENT (soil water)** - (i) A vector (macroscopic) point function that is equal to the decrease in the hydraulic head per unit distance through the soil in the direction of the greatest rate of decrease. In isotropic soils (which see) this will be in the direction of water flux; (ii) The rate of change in hydraulic head between two points indicates the direction in which water will flow.

**HYDRAULIC HEAD** - The elevation with respect to a specified reference (level), usually the soil surface, at which water stands in a piezometer connected to the point in question in the soil. Its definition can be extended to soil above the water table if the piezometer is replaced by a tensiometer.

The hydraulic head in systems under atmospheric pressure may be identified with a potential expressed in terms of the height of a water column.

**HYDRIC SOILS** - Soils that are wet long enough to periodically produce anaerobic conditions, thereby influencing the growth of plants. See wetland.

**HYDROLOGY** - The science dealing with the distribution and movement of water. See agrohydrology, ground-water hydrology, soil hydrology and surface hydrology.

**HYDROLYSIS** - (i) Chemical decomposition involving splitting of a bond and addition of water. (ii) The degradation of a contaminant by chemical reactions involving water or an aqueous solution, including soil solution. See degradation.

**HYDROPHOBIC CONTAMINANTS** - Compounds that do not have a strong affinity for water. Introduced chemical contaminants may not have an affinity for the soil water.

**HYDROPHOBIC SOILS** - Soils that are water repellent, often due to dense fungal mycelial mats or hydrophobic substances vaporized and reprecipitated during fire; certain wastes, e.g., oil wastes, also increase hydrophobicity of soils.

**HYDROSTATIC PRESSURE** - (i) The pressure exerted or transmitted by a fluid at rest. (ii) The pressure at a point in a fluid at rest due to the weight of fluid above it (gravitational pressure).

**HYDROUS OXIDE** - Water (an indefinite amount) combined with oxygen and a metal or nonmetal. Iron, aluminum and manganese hydrous oxides are prominent in many soils.

**HYPHA** - (pl. hyphae) A filament (thread) of fungus cells. A large number of hyphal filaments (hyphae) constitute a mycelium. Bacteria of the order Actinomycetes also produce branched mycelium.

**HYDROUS MICA** - A silicate clay of the 2:1 type of crystal lattice structure. See silicate clay.

**HYSTERESIS** - A nonunique relationship between two variables, wherein the curves depend on the sequences or starting point used to observe the variables. Examples include the relationships: (i) between soil water content and soil water matric potential, and (ii) between solution concentration and adsorbed quantity of chemical species, See soil water (moisture) content and soil water matric potential.

**IGNITABLE WASTE** - (i) Waste consisting of liquids with flashpoints of less than 50 °C (140 °F), or (ii) nonliquids that may cause fires through friction, or (iii) any waste consisting of ignitable compressed air or oxidizers.

**ILLITE** - A hydrous mica colloidal clay. See silicate clays.

**IMMATURE (YOUNG) SOIL** - A relatively recently formed soil which has not reached equilibrium with its environment and has only slightly formed horizons because soil forming processes have been active for only a relatively short time. (Contrast with mature soil.)

**IMMISCIBILITY** - Two phases, commonly liquids that cannot completely dissolve in one another (such as oil and water).

**IMMOBILIZATION** - The conversion of an element from the inorganic to the organic form in living tissues, microbial or plant, thereby rendering it temporarily unavailable for use.

**IMPEDED DRAINAGE** - A condition which hinders the movement of water through soils under the influence of gravity.

**IMPERVIOUS** - Soil resistance to penetration by fluids or by roots,

**IMPOUNDMENT** - A body of water or liquid chemical confined by a dam, lake, floodgate, or other confining barrier. See surface impoundment and hazardous waste surface impoundment.

**INACTIVE HAZARDOUS WASTE SITE** - See uncontrolled hazardous waste disposal site.

**INCINERATION** - (i) Burning of certain types of solid, liquid or gaseous materials. (ii) Treatment technology involving destruction of wastes by burning at high temperatures e.g., burning sludge to remove water content and reduce to ash for disposal. See disposal.

**INCOMPATIBLE WASTE** - (i) A hazardous waste which is unsuitable for placement in a particular device or facility because it may cause corrosion or decay of contaminate materials; or (ii) inability to commingle with another waste or material under uncontrolled conditions because to commingle might produce heat or pressure; fire or explosion; violent reaction; toxic ducts, mists, fumes or gases; or flammable fumes or gases.

**INDICATOR** - In biology, an organism, species, or community whose characteristics show the presence of specific environmental conditions.

**INDICATOR PLANTS** - Plants characteristic of specific soil or site conditions, whether natural or disturbed.

**INDURATED** - (i) The process of hardening, especially by increasing fibrous elements. (ii) In soil, refers to layer in which the soil particles are bound together into a hard layer by various compounds, e.g., calcium carbonate, oxides of iron, aluminum, silicon, or by humus. (iii) Rock or soil that has been hardened or consolidated by pressure or cementation.

**INDUSTRIAL WASTE** - Any solid, semisolid, liquid, or gaseous-contained waste generated by manufacturing or processing which may unreasonably endanger humans or animals and environs.

**INFERENCE ENGINE** - The software that provides the mechanism for interpreting the commands and accessing the knowledge base to solve problems in an expert system. See expert system, and knowledge base.

**INFILTRABILITY** - The flux (or rate) of water infiltration into the soil when water at atmospheric pressure is maintained on the atmosphere-soil boundary, with the flow direction being one-dimensionally downward. See soil infiltration and infiltration rate.

**INFILTRATION** - (i) The penetration of water through the ground surface into sub-surface soil or the penetration of water from the soil into sewer or other pipes through defective joints, connections, or manhole walls, (ii) A land application technique where large volumes of wastewater are applied to land, allowed to penetrate the surface and percolate through the underlying soil. Also see percolation and infiltration rate (flux).

**INFILTRATION RATE (FLUX)** - A soil characteristic determining or describing the maximum rate at which water can enter the soil under specified conditions, including the presence of an excess of water; the volume of water (or liquid chemical) infiltrated downward into the soil per unit cross-sectional soil area in unit time, with dimension of velocity.

**INFILTRATION VELOCITY** - The actual rate at which water will enter the soil through the surface; a rate which may differ from the infiltration (or basic) rate because of a limiting supply of water. See infiltration rate.

**INFORMATION FILE, Superfund** - A file that contains accurate, up-to-date documents on a Superfund site. The file is usually located in a public building such as a school, library, or city hall that is convenient for local residents.

**INJECTION WELL** - A well into which fluids are injected for various purposes such as waste disposal, improving crude oil recovery or solution mining. See deep well injection storage.

**INITIAL ENTRY PARTY (TEAM), Superfund** - The party that enters the site first, employs specialized instrumentation to characterize site hazards, becomes familiar with the conditions and dangers associated with the site. The major purpose of this team is to measure existing hazards and to survey the site to ascertain if the level of personal protection determined from preliminary assessment, site inspection, or site screening study must be adjusted.

**INORGANIC COMPLEXATION** - The attachment of a transition-metal ion to another molecule or ion by means of a coordinate covalent bond. See organic complexation, and chelates.

**INORGANIC WASTE** - Solid waste composed of matter other than plant, animal, human, and certain carbon compounds, and including metals and glass.

**INSTITUTIONAL WASTES** - Solid, semisolid, and liquid wastes generated by educational, health care, correctional, and other institutional facilities.

**INTERSTICES** - See pores, saturated zone.

**INTRINSIC PERMEABILITY** - The property of a porous material that expresses the ease with which gases or liquids flow through it. Often symbolized by  $k = K\eta/\rho g$ , where  $K$  is the Darcy hydraulic conductivity,  $\eta$  is the fluid viscosity,  $\rho$  is the fluid density, and  $g$  is the acceleration of gravity. Dimensionally,  $k$  is an area [ $L^2$ ]. See permeability, soil water, and Darcy's law.

**ION ACTIVITY** - Informally, the effective concentration of an ion in solution. Numerically, it approaches the value of the ionic concentration at infinite dilution of the ion under consideration and otherwise satisfies the formal, thermodynamic relationship between activity and chemical potential as applied to a single ionic species.

**ION EXCHANGE** - Substitution of one ion, either positive (cation) or negative (anion), for another of the same charge. A soil phenomenon whereby an introduced ion, including a contaminant ion, may replace another. See anion and cation exchange capacity.

**ION SELECTIVE ELECTRODE** - An electrochemical sensor, the potential of which (in conjunction with a suitable reference electrode) depends on the logarithm of the activity of a given ion in aqueous solution; useful for determining specific ions in soils (solutions and extracts), e.g., ammonium and nitrates. See electrochemical sensor.

**IONIC DIFFUSION** - In soils, the movement of ions, e.g., nutrients, nonnutrients and certain metal species, that result from a concentration gradient.

**IONIC SPECIES** - Chemically dissociated substances (elements) in a fluid medium, such as sodium and chloride ions formed when salt dissolves in water. Also see metal species.

**IONIC STRENGTH** - A parameter that estimates the interaction between ions in solution. It is calculated as one-half the sum of the products of ionic concentration and the square of ionic charge for all the charged species in a solution.

**IONS** - Atoms, groups of atoms, or compounds, which are electrically charged as a result of the loss of electrons (cations) or the gain of electrons (anions).

**IRON-PAN** - An indurated soil horizon in which iron oxide is the principal cementing agent. See plinthite.

**IRRIGATION** - The intentional application of water to the soil.

**ISOTROPIC SOIL** - A soil with hydraulic conductivity the same in all directions.

**JUNK** - Unprocessed and discarded materials and manufactured items usually suitable for reuse or recycling, such as glass, rags, paper, metal, some plastics, and larger items.

**KAOLINITE** - An aluminosilicate mineral of the 1 :1 crystal lattice group, consisting of one silica tetrahedral layer and one aluminum oxide-hydroxide octahedral layer. See silicate clay.

**KARST** - An irregular limestone region with sinks, underground streams and caverns. Sites located in karst topography, especially with clayey residual soils overlying limestone or dolomite with fracture and solution porosity and permeability have a high potential for contaminants to reach ground water.

**KNOWLEDGE BASE (FRAME)** - The knowledge base of an expert system that uses "expert" information to solve a problem and reach a conclusion, Features of a knowledge base consist of a set of IF --- THEN rules or other knowledge representation methods such as frames. Features are described in terms of objects and/or attributes. See also expert system, inference engine, knowledge-based system tool.

**KNOWLEDGE-BASED SYSTEM TOOL** - A tool that provides underlying links and is ideal for providing occasional access to help screens, diagrams or data bases, and neural nets (nodes) which use other types of logic to solve problems; Hypertext is an example of a knowledge-based tool. See also expert system, inference engine, knowledge base.

**KROTOVINAS** - Irregular, tubular streaks within one soil horizon consisting of the soil materials transported from another horizon; these streaks can result from the filling of tunnels made by burrowing animals, especially rodents.

**LABILE** - A substance that is readily transformed by microorganisms or is readily available to plants.

**LABORATORY WASTE** - Discarded materials which have been generated by laboratory research, processes, and analyses.

**LAGOON** - (i) A shallow channel or pond near or communicating with a larger body of water. (ii) A shallow artificial pool for storing or processing a liquid.

**LAND** - A term commonly used to include the soil and surface features for a specified situation, nature, or quality over an area considered as a unit, e.g., valley bottom land.

**LAND DISPOSAL** - Includes, but is not limited to, placement in a landfill, surface impoundment, waste pile, injection well, land treatment facility, salt dome formation, underground mine or cave, or concrete vault or bunker intended for disposal purposes.

**LAND FARMING (of wastes)** - A disposal process in which hazardous waste deposited on or in soil is degraded naturally by microbial action. See disposal, degradation.



**LANDFILL** - A disposal facility or part of a facility where wastes are placed directly in or onto the ground; not a land treatment facility, surface impoundment, or other surface repository.

**LANDFILL CELL** - A discrete portion of a hazardous waste landfill which uses some means (e.g., a liner) of providing isolation of wastes from adjacent cells or wastes.

**LANDFILL HAZARDS** - Potential hazards from landfills to include contamination of surface and ground waters, generation of toxic fumes, and human hazards from fires, explosions, and other events.

**LANDFILLING** - The covering of solid wastes in a facility to minimize leachate formation; a technology used for RCRA corrective action.

**LANDFILLS** - (i) Sanitary landfills are land disposal sites for non-hazardous solid wastes at which the waste is spread in layers, compacted to the smallest practical volume, and cover material applied at the end of each operating day. (ii) Secure chemical landfills are disposal sites for hazardous waste. They are selected and designed to minimize the chance of release of hazardous substances into the environment.

**LANDFORM** - A three-dimensional part of the land surface, formed of soil, sediment, or rock that is distinctive because of its shape, that is significant for land use or to landscape genesis; that repeats in various landscapes, and that also has a fairly consistent position relative to surrounding landforms.

**LANDSCAPE** - All the natural features such as fields, hills, forests, water, etc., which distinguish one part of the earth's surface from another part. Usually that portion of land or territory which the eye can comprehend in a single view, including all its natural characteristics.

**LARGE ANIMALS** - These include both wild and domestic animals that typically weigh more than 16.3 kg (30 pounds) when fully grown (sometimes called mega-animals).

**LAY OF THE LAND** - See topography.

**LEACHATE** - A liquid that results when water collects contaminants as it trickles through wastes, agricultural pesticides, or fertilizers. Leaching may occur in farming areas, feedlots, and landfills, and may result in hazardous substances entering surface water, ground water, or soil.

**LEACHATE SEEP** - Leachate that emerges on the ground surface.

**LEACHED** - The condition of a soil which has experienced leaching. See leachate.

**LEACHING FRACTION** - The fraction of infiltration irrigation water that percolates below the root zone. For waste sites, that fraction of infiltrate that percolates below the root (saturated) surface layers of soil.

**LEACHING REQUIREMENT** - The leaching fraction necessary to keep soil salinity, chloride, or sodium (the choice being that which is most demanding) from exceeding a tolerance level of the crop in question relevant to agriculture. For waste sites, the leaching requirements may satisfy other requirements, such as in the removal of contaminants to remediate a site. It applies to steady-state or long-term average conditions.

**LEACHING** - The dissolution and removal of substances or materials in solution from the soil by movement (percolation) of water through the soil.

**LIGANDS** - (i) A group of atoms, ions, or molecules bound to the central element (atom or ion). (ii) The molecule or ion that contains the donor atom in a complex. See complexation.

**LIGHT SOIL** - An agricultural term used to describe a soil with a high content of sand.

**LIMESTONE** - See granular rock structure.

**LIMITING FACTOR** - A condition whose absence, or excessive concentration, is incompatible with the needs or tolerance of a species or population and which may have a negative influence on their ability to grow or even survive.

**LIMNIC MATERIALS - Classified As Organic Materials** - Limnic materials include both organic and inorganic materials that were either (1) deposited in water by precipitation or through the action of aquatic organisms such as algae or diatoms, or (2) derived from underwater and floating aquatic plants and subsequently modified by aquatic animals. They include coprogenous earth (sedimentary peat), diatomaceous earth, and marl.

**LINER** - Commonly the material or continuous layer of natural or man-made materials used on the inside or beneath the surface of an impoundment, landfill, or landfill cell to prevent or restrict the downward or lateral movement or leaching of wastes, including hazardous waste constituents, to the environment.

**LIQUID CHEMICALS** - A freely flowing substance, usually other than water, obtained by a chemical process or used for producing a chemical effect.

**LIQUID LIMIT** - The minimum water mass content at which a small sample will barely flow under standard treatment. See Atterberg limits.

**LIQUID WASTE** - Water or liquid chemicals rejected after usage in communities, industry, agriculture, in other enterprises or processes. See wastewater.

**LISTED WASTE** - (i) A solid waste considered hazardous under 40 CFR 261 Subpart D. A listed waste comes from a process found to generate a hazardous waste or is a commercial chemical product that has been discarded. (ii) A hazardous waste under RCRA but which has not been subjected to the

Toxic Characteristics Listing Process because the dangers they present are considered self-evident. See also characteristic waste and delisting.

**LITTER** - The surface layer (of a forest floor) consisting of the additions of freshly fallen leaves, twigs, stems, flowers, fruits and bark.

**LOAM** - An intermediate soil texture class; loamy includes all texture classes with the words loam or loamy as part of its class name, e.g., clay loam or loamy sand. See soil texture.

**LOESS** - Material transported and deposited by wind and consisting of predominantly silt-sized particles.

**LOSS/DECAY** - The degradation of chemicals resulting in a reduction in the concentration of contaminants (in soil or ground water).

**LOW HAZARD WASTES** - Those wastes of such low combustibility that no self-propagating fire can occur.

**LOW-LEVEL RADIOACTIVE WASTE** - (i) Wastes less hazardous than most of those generated by a nuclear reactor. Usually generated by hospitals, research laboratories, and certain industries. The Department of Energy, Nuclear Regulatory Commission, and EPA share responsibilities for managing them; (ii) Defined by law as waste that is not classified as high-level waste, transuranic waste (in excess of 10 nCi/g), uranium mine and mill tailings, or spent nuclear fuels. Also compare with high-level radioactive waste.

**MACROBIOTA** - See soil macrofauna.

**MACRO CATIONS** - Major cation constituents of uncontaminated soils, including calcium, magnesium, sodium and potassium.

**MACRONUTRIENT** - A plant nutrient attaining a concentration of  $>500 \text{ mg kg}^{-1}$  in mature plants. Usually refers to nitrogen, phosphorus, potassium, calcium, magnesium and sulfur. Compare with micronutrients.

**MAP UNIT** - See soil map unit.

**MARSH** - Periodically wet or continually flooded areas with the surface not deeply submerged. Covered dominantly with sedges, cattails, rushes, or other hydrophytic plants. Subclasses include fresh-water and salt-water marshes. See swamp.

**MATRIC SUCTION** - See soil water matric potential.

**MATURE SOIL** - A soil with well-developed characteristics produced by the natural processes of soil formation, and in equilibrium with its environment.

**MEDIA** - Specific environments - air, water, soil - which are the subject of regulatory concern and activities.

**MEDIUM TEXTURED SOIL** - A soil with textural properties intermediate between those of heavy and light soils, e.g., very fine sandy loam, loam, silt loam, and silt. See soil texture.

**MESOBIOTA** - See soil mesofauna.

**METABOLISM** - The totality of the processes by which an organism uses food for production of its protoplasm, energy production, storage, or elimination as waste. Also see recalcitrant molecule.

**METAL CLEANING WASTE** - Any wastewater resulting from the cleaning of any metal process cleaning equipment.

**METAL SPECIES** - A metal entity or metal molecular particle, such as a metal ion. See ionic species.

**METAL/CYANIDE WASTE DISPOSAL RESTRICTIONS** - Any liquid containing wastes which exceed the specified concentrations of total metals or cyanides in their leachate in accordance with Code 40 CFR Part 261.

**METALS** - Elements which form positive ions when their salts are dissolved in water.

**METALLOID** - (i) A nonmetallic element, such as carbon or nitrogen, which can combine with a metal to form an alloy. See semiconductors. (ii) An element resembling a metal, such as boron and selenium.

**METEOROLOGY** - The science concerned with the atmosphere and its phenomena, i.e., temperature, density, winds, clouds, humidity, pressure, movement and other characteristics.

**MICROAEROPHILIC MICROORGANISM** - A microorganism that requires a low concentration of oxygen for growth. Sometimes used to indicate a microorganism that will carry out its metabolic activities under aerobic conditions but that will grow much better under anaerobic conditions.

**MICROBIOTA** - See soil microbiota.

**MICROCLIMATE** - (i) The climatic condition of a small area resulting from the modification of the general climatic conditions by local differences in elevation or exposure. (ii) The sequence of atmospheric changes within a very small region.

**MICROFAUNA** - Protozoa, nematodes, and arthropods of microscopic size. See protozoa, nematodes and arthropods.

**MICROFLORA** - (i) Bacteria, including actinomycetes and streptomycetes, fungi (yeasts and molds), myxomycetes, algae, including cyanobacteria, and viruses. See bacteria, actinomycetes, streptomycetes, fungi (yeasts and molds), cyanobacteria (blue-green algae) and viruses. (ii) A small or strictly localized flora.

**MICROHABITAT** - See soil microhabitat.

**MICRONUTRIENT** - A chemical element necessary for plant growth found in small amounts, usually < 100 mg kg<sup>-1</sup> in the plant. These elements consist of boron, chloride, copper, iron, manganese, molybdenum and zinc. Compare with macronutrient.

**MICROORGANISMS** - See microbiota.

**MICRORELIEF** - (i) Small scale, local differences in topography, including mounds, swales, or hills that are usually < 1 m in diameter and with elevation difference of up to 2 m. (ii) Differences in topography altered by tillage operations, generally over an area of about 1 m<sup>2</sup> with elevation differences of a few centimeters or less. See relief.

**MICROSITE** - A small volume of soil where biological or chemical processes differ from those of the soil as a whole, such as an anaerobic microsite of a soil aggregate or the surface of decaying organic residues. Microsites may be evident at waste sites, especially if waste is unevenly distributed. Also see soil microhabitat.

**MILITARY WASTES** - The wastes resulting from industrial manufacture of military items or materials, or resulting from military operations, usage, or storage, including hazardous wastes, munitions, explosives, inflammables, biological, and chemical warfare agents.

**MINE DUMPS** - (Note: obsolete.) Areas covered with overburden and other waste materials from ore and coal mines, quarries and smelters and usually with little or no vegetative cover. A miscellaneous area. See miscellaneous areas.

**MINERAL** - A naturally occurring substance with a solid, homogeneous crystalline chemical structure, occurring as individual crystals or disseminated in some other mineral or rock. Also see soil mineral.

**MINERAL SOILS** - (i) Soils consisting predominantly of, and having its properties determined predominantly by, mineral matter. Usually contains < 200 g kg<sup>-1</sup> organic carbon (< 120-180 g kg<sup>-1</sup> if saturated with water), but may contain an organic surface layer up to 30 cm thick; (ii) Soils that meet one of the following requirements: (a) Mineral soil material less than 2.0 mm in diameter (the fine-earth fraction) makes up more than half the thickness of the upper 80 cm (31 in.); or (b) The depth to bedrock is less than 40 cm and the layer or layers of mineral soil directly above the rock either are 10

cm or more thick or have half or more of the thickness of the overlying organic soil material; or (c) The depth to bedrock is 40 cm or more, the mineral soil material immediately above the bedrock is 10 cm or more thick. (See USDA Soil Survey Staff, 1990. Keys to Soil Taxonomy, SMSS Tech. Monogr. No. 19, for further details.)

**MINING WASTES** - Any waste or residues resulting from mining operations and the extractions of raw materials from the earth. (Considered by Soil Science Society of America Glossary as a "miscellaneous area.") See miscellaneous areas.

**MINOR ELEMENTS** - See micronutrients.

**MISCELLANEOUS AREAS** - A Soil Science Society of American Glossary term used for naming areas of limiting conditions, e.g., dumps, wastes, etc. A kind of map unit used in soil surveys comprised of delineations, each of which shows the size, shape and location of a landscape unit within which little or no vegetation occurs because there either is little or no soil, there are very unfavorable soil conditions, there is active erosion, washing by water, or man's activities prevent vegetation growth. See delineation and soil map unit.

**MISCELLANEOUS UNIT** - A hazardous waste management unit where hazardous waste is treated, stored, or disposed of and that is not a container, tank surface impoundment, pile, land treatment unit, landfill, incinerator, boiler, industrial furnace, underground injection well with appropriate technical standards under 40 CFR 146, or unit eligible for a research, development, and demonstration permit under §270.65.

**MITES** - Any of numerous minute or small arachnids (four pairs of thoracic appendages) that infest animals, plants, and stored foods; includes many disease vectors. See soil mesofauna, arachnids.

**MIXED WASTE** - Low-level radioactive waste (defined under the Low Level Radioactive Waste Policy Amendments Act of 1985), containing either a listed hazardous waste or a waste exhibiting hazardous waste characteristics. Mixed waste must be managed in compliance with applicable RCRA, Atomic Energy Act, and state regulations. Examples of mixed waste include lead oxide dross mixed with uranium oxides, and radionuclide-contaminated waste solvents from industry, academic institutions, and medical facilities.

**MIXING RATE** - The rate at which infiltrate and medium, e.g., soil or ground water, are combined.

**MOISTURE (WATER) CONDITIONS** - The degree or extent to which a soil holds moisture and is affected by its moisture potential and content, either long- or short-term. Also see soil water (moisture) potential.

**MOLDS** - A superficial, often woolly-type growth (of mycelia) produced on damp or decaying organic matter or living organisms. A fungus, particularly of the order Mucorales, that produces mold.

**MONITORING** - The systematic detection and measurement of the physical, chemical, biological and other components that interact in an ecosystem.

**MONITORING SURVEY, Superfund** - A survey made during initial entry to the site for a preliminary evaluation of atmospheric hazards; a surveillance monitoring program of materials detected during the initial site survey needing more comprehensive evaluation of hazards and analyses for specific components; a program established to monitor sampling and evaluate hazards for the duration of site operations; a continuous monitoring of atmospheric changes since site activities and weather conditions may change during site investigations.

**MONTMORILLONITE** - An aluminosilicate clay with a 2:1 expanding crystal lattice. See silicate clay.

**MOST PROBABLE NUMBER** - The estimation of a microbial population or density without an actual count of single cells or colonies; a dilution method of estimated population sizes based on the highest dilution at which growth can be obtained.

**MOTTLE** - A spot, blotch or patch of color or shade of color, occurring on the surface of a sediment or soil.

**MOTTLED SOIL** - A soil with spots or blotches of different color or shades of color interspersed with the dominant color, usually indicating poor aeration or seasonal wetness. May be indicative of restrictive drainage or chemical accumulations in hazardous waste sites.

**MUCK SOIL** - (i) A soil containing between 200 and 500 g kg<sup>-1</sup> of organic matter. (ii) An organic soil in which the plant residues have been altered beyond recognition. (iii) Dark, finely divided, well-decomposed organic material intermixed with a high percentage of mineral matter, usually silt.

**MUNSELL COLOR SYSTEM** - A color designation system applied to soils that specifies the relative degrees of the three simple variables of color: hue, value, and chroma. See Munsell Soil Color Chart.

**MUNSELL SOIL COLOR CHART** - An assemblage of appropriate color chips in the pages of a loose-leaf notebook by which soil colors can be matched and identified in a standardized fashion. See Munsell Color System.

**MYCELIUM** - A network of hyphae. See hypha and molds.

**MYCORRHIZA** - The association, usually symbiotic, obligatory or beneficial, of specific fungi with the roots of higher plants.

**MYXOMYCETES** - Plasmodial, or acellular, true slime molds with characteristics intermediate between the protozoa and fungi; a class of microorganisms of the division Mycota. Found especially in soils rich in organic matter.

**NATURAL AREA** - An area of land in which organisms, soils, geology, and related processes are undisturbed by man, and with as few controls as possible.

**NATURAL HAZARDS** - Detrimental occurrences brought about by the forces of nature such as floods, hurricanes, earth movements, wildfires, and volcanos. These hazardous can also be accelerated by human and/or animal activity to include erosion, acid precipitation and climate change, as well as flooding.

**NATURAL LAND VEGETATION** - Vegetation which uses soil as its growth medium, and which is not subject to extensive cultural practices. Included are naturally-occurring plants such as trees, shrubs, grasses, herbs, forbs, ferns, lichens, and algal-lichen soil crusts.

**NEMATODE** - Elongated, minute, cylindrical worms parasitic in animals or plants or free-living; any of a class or phylum Nematoda. See microfauna.

**NEUTRALIZATION** - Decreasing the acidity or alkalinity of a substance by adding it to alkaline or acid materials, respectively. See hazardous waste treatment.

**NEUTRAL SOIL** - A soil in which the surface layer, at least in the agricultural sense of the tillage zone, is the range pH 6.6 - 7.3. (Not a strict chemical definition of pH=7.0) See soil reaction.

**NICHE** - (i) The particular role that a given species plays in the ecosystem; (ii) the physical space occupied by an organism (including microorganisms).

**NITRATE** - (i) Salt or ester of nitric acid. (ii) To treat or combine with nitric acid or a nitrate.

**NONHUMIC SUBSTANCES** - The organic substances of low molecular weight, such as organic acids and gases, that are relatively soluble in the soil water when complexed with metals. Compare with humic substances.

**NONMETALS** - Elements that are ordinarily very poor conductors of electricity; their atoms have high electron affinities; high ionization energies; and, tend to form simple monatomic anions of noble gas configuration by acquiring electrons from metal atoms. They may react with each other. Representatives include hydrogen, carbon, nitrogen, phosphorus, oxygen, sulfur, fluorine, chlorine, bromine, iodine, astatine, and the noble gases: helium, neon, argon, krypton, xenon, and radon. All are found in the atmosphere except radon, which is radioactive. Only the noble gases are monatomic. Carbon and sulfur can be found in pure elemental forms in nature. All of the other nonmetals are too reactive to remain uncombined and occur naturally only in compounds.

**NON-POINT SOURCE** - Pollution sources which are diffuse and do not have a single point of origin or are not introduced into a receiving stream from a specific outlet. The pollutants are generally carried off the land by stormwater runoff. The commonly used categories for non-point sources are:



agriculture, forestry, urban, mining, construction, dams and channels, land disposal, and saltwater intrusion. Compare with point source.

**NONINDUSTRIAL WASTES** - Any wastes other than from industrial sources.

**NONSPECIFIC HAZARDOUS WASTE SOURCES** - Waste not generated from manufacturing processes, such as wastewater treatment sludges from chemical conversions, e.g., coating of aluminum; and spent halogenated solvents used in degreasing, e.g., carbon tetrachloride, chlorinated fluorocarbons, methylene chloride, tetrachloroethylene, trichloroethylene, and 1,1,1-trichloroethane.

**NUCLEAR WASTE** - Radioactive waste resulting from human activity and classified into four categories depending upon (1) origin, (2) level of radioactivity, and (3) potential hazard: high level waste; low level waste; transuranic waste; and tailings.

**NUTRIENT STRESS** - A condition occurring when inadequate nutrient supply restricts growth. See macronutrient, micronutrient, soil nutrient diffusion.

**ODOR** - The quality or character of the smell of the soil, especially when dislodged for olfactory examination.

**ODOR THRESHOLDS** - The lowest concentration of a contaminant that can be detected by odor.

**OFF-SITE FACILITY** - A hazardous waste treatment, storage, or disposal area that is located at a place away from the generating site.

**OIL DUMPING** - Usually intentional discharge of oil or oily wastes onto or within an aqueous or terrestrial surface.

**OIL WASTELAND** - Land on which oily wastes have accumulated, including slush pits and adjacent areas affected by oil waste. (Considered by Soil Science Society of America, Glossary of Soil Science Terms, as a "miscellaneous area.") See miscellaneous area.

**ON-SITE FACILITY** - A hazardous waste treatment, storage, or disposal area that is located on the generating site.

**ON-SCENE COORDINATOR (OSC), Superfund** - The predesignated EPA, Coast Guard, or Department of Defense official who coordinates and directs Superfund removal actions or Clean Water Act oil-or hazardous-spill corrective actions.

**ON-SITE INVESTIGATION, PRELIMINARY, Superfund** - An initial onsite survey to determine, on a preliminary basis, hazardous or potentially hazardous conditions.

**ON-SITE PROPERTY** - Geographically contiguous property which may be divided by public or private right-of-way, provided the entrance and exit between the properties is at a crossroads intersection, and access is by crossing, as opposed to going along the right-of-way. Noncontiguous properties owned by the same person but connected by a right-of-way, which that person controls and to which the public does not have access, are also considered on-site property.

**OPEN DUMP** - (i) Any facility or site where solid waste is disposed of which is not a sanitary landfill that meets the criteria promulgated under section 4004 of RCRA and is not a facility for disposal of hazardous waste. (All open dumps will eventually be prohibited by RCRA.) (ii) A site where solid waste is deposited on a land surface with little or no treatment. See dumps.

**OPEN LAND** - Any surface or subsurface land which is not a disposal site and is not covered by a building.

**OPEN SPACE** - Land predominately free of buildings, and sometimes protected from development; excludes land used for traffic ways, railroads, and parking lots.

**OPERABLE UNIT** - Term for each of a number of separate activities undertaken as part of a Super-fund site cleanup. A typical operable unit would be removing drums and tanks from the surface of a site.

**ORGANIC CHEMICALS/COMPOUNDS** - (i) Animal- or plant-produced substances containing mainly carbon, hydrogen and oxygen. (ii) In a hazardous waste site, may include those which are hazardous or toxic, such as pesticides.

**ORGANIC COMPLEXATION** - A process in which a metal ion is bound to nonmetal atoms (e.g., nitrogen, carbon, or oxygen) to form a heterocyclic ring having coordinate covalent bonds. See inorganic complexation and chelates; covalent bonding.

**ORGANIC MATTER** - Material of plant or animal origin that decays in the soil to form humus. See humus.

**ORGANIC RESIDUES** - Animal and vegetative material added to the soil and which are recognizable as to their origin.

**ORGANIC SOIL** - A soil which contains a high percentage ( $> 200 \text{ g kg}^{-1}$  or  $> 120\text{-}180 \text{ g kg}^{-1}$  if saturated with water) of organic carbon throughout the upper and most weathered part of the soil profile.

**ORGANIC SOIL MATERIALS (AND ORGANIC SOILS)** - (i) Are saturated with water for long periods or are artificially drained and, excluding live roots, (a) have 18 percent or more organic carbon if the mineral fraction is 60 percent or more clay, (b)' have 12 percent or more organic carbon if the mineral fraction has no clay, or (c) have a proportional content of organic carbon between 12 and 18 percent

if the clay content of the mineral fraction is between zero and 60 percent; or (ii) Are never saturated with water for more than a few days and have 20 percent or more organic carbon. Three basic kinds of organic soil materials are distinguished, fibric, hemic and sapric, according to the degree of decomposition of the original plant materials. See fibric, hemic, and sapric soil materials. Also see USDA Soil Survey Staff, 1990, Key to Soil Taxonomy, SMSS Tech. Monogr. No. 19, for details.

**ORGANIC SOIL MATERIALS, HIGHLY DECOMPOSED** - The most highly decomposed of the organic soil materials. Rubbed fiber content is <17 percent of the volume.

**ORGANIC WASTE DIGESTIBILITY** - The potential degree to which organic matter in waste water or sewage can be broken down into simpler and/or more biologically stable products.

**ORGANOMETALLIC COMPLEX** - An organic-metal complex, e.g., a humus-metal complex. See complex.

**ORGANOMETALLIC COMPOUND** - Molecules containing carbon-metal linkage.

**ORGANO-METAL CHELATE** - A chelate formed by an organic component (organic molecule) and a metal. Also see chelate.

**OVEN-DRY SOIL** - Soil that has been dried at 105 °C until it reaches constant weight (usually 24 hours).

**OVERBURDEN** - A general term referring to all the unconsolidated rock debris overlying the bedrock. Engineers sometimes use the terms overburden and soil interchangeably. Geologists commonly infer that "soil" is the upper few feet of overburden that has been obviously weathered and is often divisible into secondary zones of variable color or texture.

**OXIDATION** - Any process in which oxidation number (the positive or negative character of atoms in compounds) increases algebraically.

**OXIDES** - Binary compounds with oxygen. All metals form normal oxides with oxygen in its most common oxidation state of -2. Common oxides in soil include silicon, aluminum, iron and manganese. The alkali and alkaline earth metals also form stable compounds with anions containing two or three oxygen atoms in lower negative oxidation states, two of which are fractional. Manganese and iron oxides may be very important in retarding the migration of pollutants in soil systems.

**PANS** - Horizons or layers in soils, that are strongly compacted, indurated, or very high in clay content or other cementing minerals or chemicals.

**PARENT MATERIAL (OF SOILS)** - Unconsolidated, more or less chemically weathered mineral matter from which soils are formed.

**PARTICLE SIZE** - The effective diameter of a particle measured by sieving, sedimentation, or micrometric methods.

**PARTICLE-SIZE CLASSES** - The grain-size distribution of the whole soil; not the same as texture, which refers to the fine earth fraction, consisting of particles of < 2.0 mm diameter. Particle-size classes are a kind of compromise between engineering and pedologic (soil) classifications.

**PARTICLE-SIZE DISTRIBUTION** - The amounts of the various soil separates in a soil sample expressed as percentages by weight.

**PATHOGENS** - Microorganisms that can cause disease in other organisms or in humans, animals, and plants. They may be bacteria, viruses, or parasites and are found in sewage, in runoff from animal farms or rural areas populated with domestic and/or wild animals, and in water used for swimming. Fish and shellfish contaminated by pathogens, or the contaminated water itself, can cause serious illnesses.

**PED** - An individual natural soil aggregate such as a crumb, prism or block, in contrast to a clod, which results from digging or other soil disturbance. See crumb, prism, block, clod.

**PEDOLOGICAL FEATURES** - Recognizable units within a soil material which are distinguishable from the enclosing material for any reason such as origin (deposition as an entity), differences in concentration of some fraction of the plasma, or differences in arrangement of the constituents (fabric).

**PEDON** - A three-dimensional body of soil with lateral dimensions large enough to permit the study of horizon shapes and relations. Its area ranges from 1 to 10 square meters. Where horizons are intermittent or cyclic, and recur at linear intervals of 2 to 7 m, the pedon includes one-half of the cycle. Where the cycle is < 2 m, or all horizons are continuous and of uniform thickness, the pedon has an area of approximately 1 square meter. If the horizons are cyclic, but recur at intervals > 7 m, the pedon reverts to the 1 square meter size, and more than one soil will usually be represented in each cycle.

**PENETRABILITY** - The ease with which a probe can be pushed into the soil. (May be expressed in units of distance, speed, force, or work depending on the type of penetrometer used.) Chemical wastes may alter soil penetrability.

**PENETROMETER** - A device used to determine soil hardness, particularly the soil surface. Penetration units are measured in lb/in<sup>2</sup> or kg/cm<sup>2</sup>.

**PERCHED WATER** - Ground water that is not confined and is separated from an underlying main body of ground water by an unsaturated zone.

**PERCHED WATER TABLE** - The apparent water table or upper surface of a body of perched water.

**PERCOLATION, SOIL WATER** - The downward movement of water through soil and radially through the sub-surface soil layers, usually continuing downward to the ground water. Especially, the downward flow of water in saturated or nearly saturated soil at hydraulic gradients of the order of 1.0 or less. See hydraulic gradient.

**PERMAFROST** - A soil layer in which the temperature is perennially at or below 0 °C, whether the consistence is very hard or loose. Dry permafrost has loose consistence.

**PERMANENT WILTING POINT** - The largest water content of a soil at which indicator plants, growing in that soil, wilt and fail to recover when placed in a humid chamber. Often estimated by the water content at -1.5 MPa soil matric potential (15 bar water.) 1 MPa (megapascal) = 10 bars (atmosphere). Also see soil water matric potential.

**PERMEABILITY** - The rate at which liquids pass through soil or other materials in specified direction.

**PERMEABILITY COEFFICIENT** - See hydraulic conductivity.

**PERMIT** - An authorization, license, or equivalent control document issued by EPA or an approved state agency to implement the requirements of an environmental regulation; e.g., a permit to operate a wastewater treatment plant or to operate a facility that may generate harmful emissions.

**PERSISTENCE** - Refers to the length of time a compound, once introduced into the environment, stays there. A compound may persist for less than a second or indefinitely.

**PERTURBED SOILS** - Soils that have been contaminated or polluted and that have received undesirable elements or materials from an external source not endemic to the soil system.

**PESTICIDE** - Any chemical substance or compound, or mixture of these, applied to plants, soils, seeds, water, food or other contact point for the purpose of preventing, inhibiting, repelling, mitigating or destroying pests. Can also include plant regulators, defoliants or desiccants derived from mineral substance. Pesticides are named according to their intended control purposes: algicides, bactericides, fungicides, herbicides, insecticides, molluscicides, nematocides, ovicides, rodenticides, and vivucides.

**pH** - See soil reaction (pH).

**PHASE** - The homogenous part of a system in contact with, but separate from other parts of the system.

**PHOSPHATES** - (i) A salt or ester of a phosphoric acid ( $\text{H}_3\text{PO}_4$ ). (ii) An organic compound of  $\text{H}_3\text{PO}_4$  in which the acid group is bound to nitrogen or a carboxyl group in a way that permits useful energy to be released (as in metabolism). (iii) The trivalent anion  $\text{PO}_4$  derived from  $\text{H}_3\text{PO}_4$ .

**PHOTODEGRADATION** - Decomposition of a compound by radiant energy. See degradation.

**PHYLLOSILICATE MINERAL TERMINOLOGY** - Phyllosilicate minerals have layer structures composed of shared octahedral and tetrahedral sheets.

**PIEZOMETER** - An instrument for measuring pressure or compressibility, especially one for measuring the change of pressure of a material subjected to hydrostatic pressure. Also see hydraulic head and tensiometer.

**PITS** - Open excavations from which soil and, commonly, underlying material have been removed, exposing either rock or other material that supports few or no plants. Soil pits are commonly excavated to reveal the soil profile and for collection of depth samples of soil. See soil profile.

**PLANT ANALYSIS** - Analytical procedures to usually determine the nutrients of plants or plant parts. See foliar analysis and foliar diagnosis.

**PLANT TYPE** - The kind of vegetation, e.g., grasses, shrubs, herbs, forbs, trees, etc. or more exactly, the genus, species and possible variety of plant.

**PLASTIC LIMIT** - The minimum water mass content at which a small sample of soil or soil material can be deformed without rupture. See Atterberg limits.

**PLASTIC SOIL** - A soil capable of being molded or deformed continuously and permanently, by relatively moderate pressure, into various shapes. See consistency.

**PLATE (PLATEY)** - A unit, type or class of soil structure with plate-like aggregates. See aggregates.

**PLASMA** - See soil plasma.

**PLATE COUNT** - A count of the number of colonies formed on a solid culture medium when inoculated with a small amount of soil. The technique is used to estimate the number of certain organisms present in the soil sample.

**PLINTHITE** - A nonindurated mixture of iron and aluminum oxides, clay, quartz, and other diluents that commonly occurs as red soil mottles usually arranged in platy, polygonal, or reticulate patterns. Plinthite changes irreversibly to ironstone hardpans or irregular aggregates on exposure to repeated wetting and drying.

**PLUME** - (i) A visible or measurable discharge of a contaminant from a given point of origin; can be visible or thermal in water, or visible in the air as, for example, a plume of smoke. (ii) The area of measurable and potentially harmful radiation leaking from a damaged reactor. (iii) The distance from a toxic release considered dangerous for those exposed to the leaking fumes.

**POINT SOURCE** - A stationery location or fixed facility from which pollutants are discharged or emitted. Also, any single identifiable source of pollution, e.g., a pipe, ditch, ship, ore pit, factory smokestack. Compare with non-point source.

**POISED SOIL SYSTEM** - A soil system that is buffered against potential changes such as when subjected to external effects, e.g., waterlogging or the addition of waste materials and other contaminants. A system which has a stabilized redox potential is said to be "well-poised." See redox potential.

**POLLUTANT** - Generally, any substance introduced into the environment that adversely affects the usefulness of a resource.

**POLLUTANT PERSISTENCE** - The retention by certain pollutants of their toxic strength for periods varying from hours, as for certain bacteria, or for thousands of years, as for some radioactive materials; also, resistance to dilution, removal, elimination, or biodegradation by organisms or in media.

**POLLUTANTS, CONVENTIONAL** - Statutorily listed pollutants which are understood well by scientists. These may be in the form of organic wastes, sediments, acids, bacteria and viruses, nutrients, oil and grease, or heat.

**POLLUTION** - The impairment of the quality of some portion of the environment by the addition of or subjection to harmful impurities, substances, or materials.

**POLLUTION PREVENTION** - Any source reduction or recycling activity that results in reduction of total volume of hazardous waste, reduction of toxicity of hazardous waste, or both, as long as that reduction is consistent with the goal of minimizing present and future risks to public health and the environment.

**POLYGONS** - In geology, a ground surface consisting of polygonal (Le., a closed plane figure bound by straight lines) arrangement of rock, soil and vegetation formed on a level or gently sloping surface by the action of frost. See fragipan.

**POLYPEDON** - A group of contiguous similar pedons. The limits of a polypedon are reached at a place where there is no soil or where the pedons have characteristics that differ significantly. Also see pedon and soil series.

**POLYVINYL CHLORIDE (PVC)** - A tough, environmentally indestructible plastic that releases hydrochloric acid when burned.

**POND** - A still body of water smaller than a lake, often of artificial construction.

**POPULATION** - A group of interbreeding organisms of the same kind occupying a particular space. Generically, the number of humans or other living creatures in a designated area.

**PORE** - See soil pore, porosity.

**PORE GEOMETRY** - The configuration and shape of the soil pores (voids).

**POROSITY** - The volume percentage of the total bulk of soil not occupied by solid particles.

**POTENTIALLY RESPONSIBLE PARTY (PRP), Superfund** - Any individual or company - including owners, operators, transporters, or generators - potentially responsible for, or contributing to, the contamination problems at a Super-fund site. Whenever possible, EPA requires PRPs, through actions, to clean up hazardous waste sites PRPs have contaminated.

**PPM/PPB** - Parts per million/parts per billion, a way of expressing tiny concentrations of pollutants in air, water, soil, human tissue, food, or other products.

**PRECIPITATION, CHEMICAL** - (i) The process of producing a separable condensed (solid) phase within a liquid medium as a result of slow chemical reaction. (ii) Removal of solids from liquid waste; removal of particles from airborne emissions. Compare with precipitation, meteoric.

**PRECIPITATION (METEORIC)** - (i) Atmospheric precipitation. (ii) Usually rainfall, but includes all forms of precipitation of atmospheric moisture, e.g., ice, snow, etc. Three types of rainfall are generally recognized depending upon differences in air temperature, density, pressure, and movement.

**PRELIMINARY ASSESSMENT** - The process of collecting and reviewing available information about a known or suspected waste site or release.

**PRESSURE HEAD** - The height to which water will rise above the bottom of a vertical, open-ended tube inserted to a point where the pressure head is to be measured.

**PREVENTION** - Measures taken to minimize the release of wastes to the environment.

**PRIORITY POLLUTANTS** - A list of toxic pollutants for which the EPA is required to publish effluent standards under Sec 307 of the Clean Water Act of 1977.

**PRISM (PRISMATIC)** - A unit type or class of soil structure with prismatic-like aggregates. See aggregates, ped.

**PRODUCTIVE SOIL** - A soil in which the chemical, physical, and biological conditions are favorable for the economic production of crops suited to a particular area. Also see fertile soil.



**PROJECT DESCRIPTION, Superfund** - Defines the goals of the project and describes how the information necessary to meet the project goals will be obtained. The project description should provide enough information to judge the appropriateness and adequacy of the quality assurance, work, or sampling plans. See US EPA, 1987, A Compendium of Super-fund Field Operations Methods, EPA/540/P-87/001, for further details.

**PROTOZOA** - Minute or microscopic protoplasmic acellular or unicellular animals with varied morphology and physiology and often complex life cycles, found in almost every kind of habitat; any member of the phylum or subkingdom Protozoa. See microfauna.

**PUDDLED SOIL** - A soil that is dense, massive and artificially compacted when wet and has no regular structure. The condition commonly results when the soil is manipulated (tilled) when a clayey soil is wet.

**QUALITY ASSURANCE PROJECT PLAN (QAPjP), Superfund** - The policies, organization, objectives, functional activities, and specific QA and Quality Control (QC) activities designed to achieve the data quality goals of the specific project(s) or continuing operation(s).

**QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)** - A system of procedures, checks, audits, and corrective actions to ensure that all EPA research design and performance, environmental monitoring and sampling, and other technical and reporting activities are of the highest achievable quality.

**QUARTZITE** - See granular rock structure.

**RADIATION** - Any form of energy propagated as rays, waves, or streams of energetic particles. The term is frequently used in relation to the emission of rays from the nucleus of an atom.

**RADIOACTIVE SUBSTANCES** - Substances that emit radiation.

**RADIOACTIVE TAILINGS** - Radioactive rock and soil which are the by-products of uranium mining and milling; they principally contain small amounts of radium which decays to emit radon, a radioactive gas.

**RADIOACTIVE WASTES** - Waste materials and substances from industry or institutions (including nuclear power plants and uranium mines and mills) that spontaneously emit alpha or beta rays and sometimes gamma rays. Radioactive waste material can also be gaseous as well as liquid and solid.

**RCRA** - Resource Conservation and Recovery Act. Enacted in 1976 as an amendment to the Solid Waste Disposal Act (SWDA). The primary objectives of the Act are to protect human health and the environment, and to conserve valuable material and energy resources. RCRA concentrates on active, controlled solid waste facilities. Compare with CERCLA. See Solid Waste Disposal Act.

**REACTIVE HAZARDOUS WASTE** - Waste that may react spontaneously, react violently with water, or that may generate toxic fumes when mixed with water or exposed to basic or mild acidic conditions.

**RECALCITRANT MOLECULES** - Molecules that persist in the environment and are resistant to degradation by physical (e.g., ultraviolet light), chemical (e.g., hydrolysis, oxidation/reduction) or biological (e.g., metabolism) factors.

**RECONSTRUCTED SOILS** - Disturbed soils, or unconsolidated geologic materials of soil size fractions, that are replaced in a vertical sequence of such quality and thickness that they provide a favorable medium for plant growth or other desirable purpose.

**RECYCLABLE MATERIALS, Superfund** - Hazardous wastes reclaimed to recover a usable product. The generation, transportation, and storage of recyclable materials are subject to RCRA requirements under CFR Parts 262, 263, and 264.

**RECYCLABLE WASTES** - See recyclable materials.

**REDOX POTENTIAL (Eh)** - The potential that is generated between an oxidation or reduction half-reaction and the hydrogen electrode in the standard state. See soil redox potential.

**REDOX REACTIONS** - Oxidation-reduction reactions; reactions in which oxidation and reduction occur together.

**REDUCTION** - Any process in which oxidation number (the positive or negative character of atoms in compounds) decreases algebraically.

**REFUSE** - A term generally used for all solid waste substances and materials.

**REGIONAL PROJECT (PROGRAM) OFFICER (RPO), Superfund** - The EPA individual who oversees implementation of a program at the EPA regional level; a Project Officer at EPA Headquarters is responsible for program guidance agency-wide.

**REGIONAL RESPONSE TEAM (RRT), Superfund** - Representatives of federal, local, and state agencies who may assist in coordination of activities at the request of the On-Scene Coordinator before and during a Superfund response action.

**RELATIVE HUMIDITY** - The amount of water vapor the air is holding expressed as a percentage of the amount the air could hold at that particular temperature.

**RELIEF** - Refers to elevations or differences in elevations, considered collectively, of a land surface on a broad scale. Also see microrelief.

**REMEDIAL INVESTIGATION** - An in-depth study designed to gather the data necessary to determine the nature and extent of contamination at a Superfund site; establish criteria for cleaning up the site; identify preliminary alternatives for remedial actions; and support the technical and cost analyses of the alternatives. The remedial investigation is usually done with the feasibility study. Together they are usually referred to as the "RI/FS."

**REMEDIAL PROJECT MANAGER (RPM)** - The EPA or state official responsible for overseeing remedial action at a site.

**REMEDIAL RESPONSE** - A long-term action that stops or substantially reduces a release or threat of a release of hazardous substances that is serious but not an immediate threat to public health.

**REMEDIATION** - A measure or solution that resolves a particular problem of a contaminated site (such as for site cleanup).

**REMOTE SENSING** - In the broadest sense, the measurement or acquisition of information of some property of an object or phenomenon, by a recording device that is not in physical or intimate contact with the object or phenomenon under study; e.g., the utilization at a distance (as from aircraft, spacecraft, or ship) of any device and its attendant display for gathering information pertinent to the environment, such as measurements of force fields, electromagnetic radiation, or acoustic energy.

**REMOVAL ACTION** - Short-term immediate actions taken to address releases of hazardous substances that require expedited response. See cleanup.

**REPORTABLE QUANTITY (RQ)** - The quantity of a hazardous substance that triggers reports under CERCLA. If a substance is released in amounts exceeding its RQ, the release must be reported to the National Response Center, the State Emergency Response Commission, and community emergency coordinators for areas likely to be affected. See CERCLA.

**RESISTANCE** - For plants and animals, the ability to withstand poor environmental conditions and/or attacks by chemicals or disease. The ability may be inborn or developed. See ecological amplitude, tolerance.

**RESPONSE ACTION** - A CERCLA-authorized action involving either a short-term removal action or a long-term removal response that may include but is not limited to: removing hazardous materials from a site to an EPA-approved hazardous waste facility for treatment, containment, or destruction; containing the waste safely on-site; destroying or treating the waste on-site; and identifying and removing the source of ground-water contamination and halting further migration of contaminants. See cleanup and CERCLA.

**REVTMENT** - A retaining wall.

**REYNOLDS NUMBER** - A number for porous media based on the Darcy velocity and the average particle diameter. For most subsurface flow systems, the Reynolds number is  $<1$ , well below the range of turbulent flow.

**RISK ASSESSMENT** - (i) The qualitative and quantitative evaluation performed in an effort to define the risk posed to human health and/or the environment by the presence or potential presence and/or use of specific pollutants. (ii) In the RCRA process, risk assessment is an effort to characterize the potential health risks posed by a hazardous waste site subject to RECRA requirements.

**ROOT QUANTITY CLASSES** - A description of roots according to the numbers of each size of root per unit area.

**ROOT SIZES** - A description of roots according to their sizes,  $<1$  mm in diameter to  $>5$  mm in diameter.

**ROOT ZONE** - The part of the soil occupied by roots, or subject to such occupation under normal conditions.

**ROOTS** - Usually the underground parts of seed plant bodies that function as organs of absorption, aeration, and food storage or as a means of anchorage and support, and differ from stems, especially in lacking nodes, buds, and leaves.

**ROTIFERS** - Any of a class Rotifera of the phylum Aschelminthes. Minute, usually microscopic, but many-celled aquatic and wet soil invertebrate animals having the anterior end modified into a retractile disk bearing circles of strong cilia that often give the appearance of rapidly revolving wheels. See soil microbiota.

**RUBBISH** - Solid waste, excluding food waste and ashes, from homes, institutions, and workplaces.

**RUNOFF** - That portion of meteoric precipitation that flows over the ground surface and enters drainage channels, streams, and rivers. It can carry pollutants from the air or land into the receiving waters.

**RUNON** - Any water, leachate, or liquid which flows from offsite to onsite.

**SALINE SOIL** - A nonsodic soil containing sufficient soluble salts to adversely affect the growth of most crop plants. Compare with sodic soil.

**SALTS** - Ionic compounds composed of the cations of bases and the anions of acids. The salts formed in reactions are soluble in water and remain in solution as dissociated ions, e.g., table salt, sodium chloride.

**SALT-AFFECTED SOIL** - Soil that has been adversely modified for the growth of most crop plants by the presence of soluble salts, exchangeable sodium, or both.

**SALT TOLERANCE** - The ability of plants to resist the adverse, nonspecific effects of excessive salts in the rooting medium (saturated zone).

**SAMPLE** - See sample, Superfund and soil sample.

**SAMPLE CONTROL, Superfund** - Records that include sample identification tags, sample traffic reports, chain-of-custody, receipt-for sample forms, Field Investigation Team (FIT) receipts, field notebooks, airbills or bills of lading, dioxin analysis forms (as applicable), and photographic logs, See US EPA, 1987, A Compendium of Super-fund Field Operations Methods, EPA/540/P-87/001, for further details.

**SAMPLE, HIGH CONCENTRATION, Superfund** - At least one contaminant is present at a level > 15%. Samples from drums and tanks are assumed to be high concentration unless information indicates otherwise.

**SAMPLE, LOW CONCENTRATION, Superfund** - The contaminant of highest concentration is present at <10 ppm. Examples include background environmental samples.

**SAMPLE MATRIX, Superfund** - Media from which the sample is collected (e.g., soil, ground water, and surface water).

**SAMPLE, MEDIUM CONCENTRATION, Superfund** - The contaminant of highest concentration is present at a level >10 ppm and less than 15% (150,000 ppm). Examples include material onsite that is obviously weathered.

**SAMPLE SPLITS, Superfund** - An aliquot of the original sample or a sample similar in all characteristics, and shared with an owner, operator, government agency or other designated body.

**SAMPLE, Superfund** - Physical evidence collected for environmental measuring and monitoring. Evidence includes remote sensing and photographs. Also see soil sample.

**SAMPLES, HAZARDOUS WASTE, RCRA** - Samples defined in 40 CFR 261.3 as samples of soil, waste, water or air collected for the sole purpose of testing to determine its characteristics or composition in accordance with the specified regulation and designated as hazardous,

**SAMPLING ACTIVITIES, Superfund** - The selection, procurement, transport, relaying of sampling information, shipping information, problems encountered during sampling, and any changes from the originally scheduled sampling program, analysis and results of sampling. See US EPA, 1987, A Compendium of Superfund Field Operations Methods, EPA/540/P-87/001, for additional details and sequence of the routine sampling process.

**SAMPLING PLAN, Superfund** - A program of action that is developed prior to field activities and that describes the methods and procedures for obtaining representative portions of the environment being investigated.

**SAMPLING PROCESS, ROUTINE, Superfund** - See sampling activities, Superfund.

**SAND** - (i) A soil particle between 0.05 and 2.0 mm in diameter. (ii) Any one of five soil separates, namely: very coarse sand, coarse sand, medium sand, fine sand, and very fine sand. (iii) A soil textural class. See soil separates and soil texture.

**SANDSTONE** - See granular rock structure.

**SANITARY LANDFILL** - A site where solid waste is deposited on or within a land surface, and subsequently compacted and covered with soil to contain or restrict movement of deposited materials.

**SAPRIC SOIL MATERIALS** - One of three kinds of basic organic soil material. These are the most highly decomposed (rotten) of the organic materials. They normally have the smallest amount of plant fiber, the highest bulk density, and the lowest water content on a dry-weight basis at saturation. They are commonly very dark gray to black. They are relatively stable, i.e., they change very little physically and chemically with time in comparison to the others. Also, see fibric and hemic soil materials.

**SARA** - Superfund Amendment and Reauthorization Act of 1986. A 5-year extension and expansion of CERCLA. See Superfund.

**SATURATE** - (i) To fill all the pores (voids) between soil particles with a liquid. (ii) To form the most concentrated solution possible under a given set of physical conditions in the presence of an excess of the solute. (iii) To fill to capacity, as the adsorption complex with a cation species; e.g.,  $H^+$ -saturated, etc.

**SATURATED SOIL** - A soil with the pore spaces (voids) completely filled with water.

**SATURATED SOLUTION** - A solution in which the concentration of dissolved solute is equal to that which would be in equilibrium with undissolved solute under the given conditions (temperature and pressure).

**SATURATED ZONE** - A subsurface zone or layer in which water fills the interstices (pores) and is under greater than atmospheric pressure.

**SATURATED ZONE THICKNESS** - The width of the zone in which the pores (voids) in the rock or soil are filled with water at pressure greater than atmospheric. The water table is the top of the saturated zone in an unconfined aquifer. Also see unsaturated zone thickness.

**SATURATION EXTRACT** - A soil sample brought to saturation point by the addition of water and stirring. The saturation extract is used to determine the soluble salts and exchangeable sodium content of the soil. See soil saturation point.

**SECONDARY MINERAL** - A mineral produced in an enclosing rock after the rock was formed through weathering or metamorphic activity, usually at the expense of a primary material in existence earlier.

**SECONDARY SOIL PARTICLES** - See aggregate, structure grades.

**SEDIMENTS** - Soil, sand and minerals washed from land into water, usually after rain. They pile up in reservoirs, rivers, and harbors, destroying fish-nesting areas and holes of water animals and clouding the water so that needed sunlight might not reach aquatic plants. Careless farming, mining, and building activities will expose sediment materials, allowing them to be washed off the land after rainfalls.

**SEEPAGE** - The loss of water from a channel or water course by percolation of the water through the natural channel bed or the material used to form the channel. May also be observed in an excavated soil.

**SEMICONDUCTING ELEMENTS** - Metalloids. Elements intermediate in properties between metals and nonmetals. These elements resemble metals in appearance (grey, metallic luster), but are more like nonmetals in their chemical behavior. They conduct electric current, but much less effectively than metals. Semiconducting elements generally form covalent compounds. These seven elements are boron, silicon, germanium, arsenic, antimony, selenium and tellurium. Their halides, like those of nonmetals are volatile and covalent. The oxides are acidic, except for two,  $\text{As}_2\text{O}_3$  and  $\text{Sb}_2\text{O}_3$ , which are amphoteric.

**SEMIVOLATILE COMPOUNDS, Superfund** - Carbon-containing chemical compounds that at a relatively low temperature fluctuate between a vapor state and a liquid compound, e.g., nail polish remover. See semivolatile organics.

**SEMIVOLATILE ORGANICS** - (i) Those organic compounds having vapor pressures between  $10^{-1}$  and  $10^{-7}$  mmHg. (ii) Those organic compounds amenable to extraction with an organic solvent. See CLP (and also refer to its Statement of Work) and semivolatile compounds.

**SEPTIC TANK** - An underground storage tank for wastes from homes not having sewer line to a treatment plant. The waste goes directly from the home to the tank, where the organic waste is decomposed by bacteria and the sludge settles to the bottom. The effluent flows out of the tank into the ground through drains; the sludge is pumped out periodically.

**SERPENTINE** - A mineral or rock of a hydrous magnesium silicate,  $\text{Mg}_3\text{Si}_2\text{O}_5 \cdot 2\text{H}_2\text{O}$ , usually having a dull green color and oftentimes a mottled appearance,

**SESQUIOXIDES** - A general term for oxides and hydroxides of iron and aluminum,

**SETTLING POND** - A natural or artificial pond for recovering the solids from an effluent. See pond, hazardous waste surface impoundment.

**SEWAGE** - The waste and wastewater produced by residential and commercial establishments and discharged into sewers.

**SILICA** - Silicon dioxide occurring in crystalline, amorphous, and impure forms (as in quartz, opal, and sand respectively).

**SILICA-ALUMINA RATIO** - The molecules of silicon dioxide ( $\text{SiO}_2$ ) per molecule of aluminum oxide ( $\text{Al}_2\text{O}_3$ ) in clay minerals or in soil.

**SILICA-SESQUIOXIDE RATIO** - The molecules of silicon dioxide ( $\text{SiO}_2$ ) per molecule of aluminum oxide ( $\text{Al}_2\text{O}_3$ ) plus ferric oxide ( $\text{Fe}_2\text{O}_3$ ) in clay minerals or in soils.

**SILICATE CLAY** - See the three main groups of silicate clays: kaolinite, montmorillonite, and hydrous mica.

**SILT** - One of the textured classes of soil particles; A soil separate consisting of particles between 0.05 and 0.002 mm in equivalent diameter. See soil separates and soil texture.

**SITE** - (i) In ecology, an area described or defined by its biotic, climatic, and soil conditions as related to its capacity to produce vegetation. (ii) An area sufficiently uniform in biotic, climatic, and soil conditions to produce a particular climax vegetation.

**SITE CHARACTERIZATION** - For a RCRA Part B Permit Application for land treatment facilities landfills, or surface impoundment, information is required on baseline environment, climatology, hydrogeology, and a ground water monitoring plan.

**SITE EVALUATION** - An evaluation of the site for specific purposes, e.g., in conformance with DQOA, CERCLA or RCRA requirements. May include residual hazardous constituents, contaminant media and route characteristics, decomposition and immobilization processes affecting migration, plant and/or animal toxification, certain aspects to elucidate site modification or management to improve protection of human health, etc.

**SITE INSPECTION** - The collection of information from a Super-fund site to determine the extent and severity of hazards posed by the site. It follows and is more extensive than a preliminary assessment. The purpose is to obtain information necessary to score the site, using the Hazard Ranking System, and to determine if the site presents an immediate threat that requires prompt removal action.



**SITE LOCATION** - The position of the site, and including the potential migration of contaminants through the soil to ground water, or in runoff off-site.

**SITE MANAGER (SM), Superfund** - The individual responsible for the successful completion of a work assignment within budget and schedule. The person is also referred to as the Site Project Manager or the Project Manager and is typically a contractor's employee, but may be an employee of EPA, state agency, or Potentially Responsible Party (PRP).

**SITE SURVEY AND RECONNAISSANCE, PRELIMINARY, Superfund** - The gathering of as much information as possible concerning the hazard, degree of hazards, and risks that may exist, including off-site studies so that the Field Investigation Team (FIT) will assess the hazards and identify the initial safety hazards. See US EPA, 1987, A Compendium of Superfund Field Operations Methods, EPA/540/P-87/001, for additional details.

**SLAKING** - In geology, (i) crumbling and disintegration of earth materials when exposed to air or moisture, or (ii) breaking up of dried clay when saturated with water. See hardpan.

**SLICKENSIDES** - Polished and grooved surfaces produced by one mass sliding past another. Slickensides are common in vertisols (soils with 30% or more clay).

**SLOPE** - The surface properties of the soil in terms of gradient, complexity, configuration, length, and aspect; a property of the soil, not a landform.

**SLOPE GRADIENT** - The inclination of the soil surface from the horizontal. The difference in elevation between two points is expressed as a percentage of the distance between those points.

**SLUDGE** - Any solid, semisolid, or liquid waste generated from a municipal, commercial, or industrial waste water treatment plant, water supply treatment plant, or air pollution control facility exclusive of the treated effluent from the waste water treatment plant.

**SMALL ANIMALS** - These include both birds and animals that typically weigh less than 16.3 kg (30 pounds) when mature.

**SODIC SOIL** - A nonsaline soil containing sufficient exchangeable sodium to adversely affect crop production (and other vegetation) and soil structure under most conditions of soil and plant type. Compare with saline soil.

**SOIL** - (i) The unconsolidated mineral material on the immediate surface of the earth that serves as natural medium for the growth of land plants. (ii) The unconsolidated mineral matter on the surface of the earth that has been subjected to and influenced by genetic and environmental factors of parent material, climate (including moisture and temperature effects), macro-, meso-, and micro-organisms, and topography, all acting over time and producing a product, soil, that differs from the material from which it is derived in many physical, chemical, biological, and morphological properties and

characteristics. (iii) A dynamic natural body on the surface of the earth in which plants grow; composed of mineral and organic materials and living forms. See also fertile soil, organic soil, organic soil materials, overburden, parent material, productive soil, subsoil, surface soil.

**SOIL ADMIXTURE** - A material added to soil, such as organic matter or limestone, to produce the desired effect. May also include addition of certain wastes.

**SOIL ADSORPTION FIELD** - A sub-surface area containing a trench or bed with clean stones and a system of distribution piping through which treated sewage may seep into the surrounding soil for further treatment and disposal.

**SOIL AGGREGATE** - See aggregate.

**SOIL AIR** - The gaseous phase found within the soil, occupying the soil pores (voids) not filled with water.

**SOIL ANALYSIS** - Analytical procedures to determine the properties of a soil; physical, chemical, biological, and mineralogical.

**SOIL ASSOCIATION** - A kind of map unit used in soil surveys comprised of delineations, each of which shows the size, shape, and location of a landscape unit composed of two or more kinds of component soils or component soils and miscellaneous areas, plus allowable inclusions in either case.

**SOIL BIOLOGY** - See soil microbiology.

**SOIL BIOSEQUENCE** - Related soils that differ from each other primarily in numbers and kinds of soil microorganisms.

**SOIL BUFFER COMPOUNDS** - The solid and solution phase components of soils that resist appreciable pH change in the soil solution, i.e., carbonates, phosphates, oxides, phyllosilicates, and some organic materials.

**SOIL BUFFER POWER** - The ability of ions associated with the solid phase to buffer changes in ion concentration in the solution phase.

**SOIL BUFFERING CAPACITY** - The resistance exhibited by a soil (solution) to a change in its pH. Buffering capacity is related to cation exchange capacity (CEC); soils with high CEC are the most strongly buffered; buffering action is due mainly to clay and very fine organic matter.

**SOIL CHARACTERISTICS** - Soil features or parameters which can be described or measured by field or laboratory observations, e.g., color, temperature, water content, structure, pH, and exchangeable cations. Often used interchangeably with soil properties.

**SOIL CHEMICAL PROPERTIES** - Those characteristics, processes, or reactions of a soil which are caused by chemical means and which can be described by, or expressed in, chemical terms or equations. Sometimes confused with, and difficult to separate from, physical properties; hence, the terms “physical-chemical” or “physicochemical.” Examples are pH, cation and anion exchange capacity, organic matter content and characterization; elemental analysis, etc. See soil physical properties.

**SOIL CHEMISTRY** - The branch of soil science that deals with the chemical constitution, chemical properties, and chemical reaction of soils.

**SOIL CLASS** - A group of soils having a definite range in a particular property such as acidity, degree of slope, texture, structure, land-use capability, degree of erosion, or drainage. See soil texture and soil structure.

**SOIL CLASSIFICATION** - The systematic arrangement of soils into groups or categories on the basis of their characteristics. Broad groupings are made on the basis of general characteristics, and subdivisions on the basis of more detailed differences in specific properties. See soil survey.

**SOIL COMPLEX** - (i) A kind of map unit used in soil surveys comprised of delineations, each of which shows the size, shape and location of a landscape unit composed of two or more kinds of component soils, or component soils and a miscellaneous area, plus allowable inclusions in either case. The bodies of component soils and the miscellaneous area are too small to be individually delineated at the scale of 1:24,000. Several to numerous bodies of each kind of component soil or the miscellaneous area are apt to occur in each delineation. The proportions of the components may vary appreciably from one delineation to another and all of the components need not occur in every delineation though they will be present in most delineations. (ii) Formerly defined as in(i) but the scale of mapping was not specified.

**SOIL CONDITIONER** - An organic material like humus or compost that helps soil absorb water, build a bacterial community, and distribute nutrients and minerals.

**SOIL CONTAMINANT MIGRATION** - See contaminant migration.

**SOIL CONTAMINATION** - See soil pollution.

**SOIL CREEP** - Slow mass movement of soil and soil material down relatively steep slopes, primarily under the influence of gravity but facilitated by saturation with water and by alternate freezing and thawing. Also see solifluction.

**SOIL CRUMBS** - See aggregate.

**SOIL CRUST** - A soil-surface layer, ranging in thickness from a few millimeters to a few tens of millimeters, that is much more compact, hard, and brittle, when dry, than the material immediately

beneath it. Crust formation may be exacerbated or disrupted by application of chemicals to the soil surface. Also see desert crust.

**SOIL DEGRADATION** - The process of changing a soil from one “type” to a more highly leached one.

**SOIL DEPTH** - Soils may be classed as micro, shallow, or deep in depth. Micro is < 18 cm through diagnostic horizons; two depths are shallow, based upon horizons, great soil groups and subsoil groups; < 50 cm and < 100 cm. Refer to USDA Soil Survey Staff, 1990, Key to Soil Taxonomy, SMSS Tech. Monogr. No. 19, for additional details.

**SOIL DESCRIPTION** - Any data, quality, characteristic, property, or parameter used to define the nature and extent of a soil by any of its common attributes. Attributes are usually obtained by sampling and analysis or in situ measurements and observations.

**SOIL DISCONTINUITY** - A significant change in particle-size distribution or mineralogy that indicates a difference in the material from which the horizon is formed and/or a significant difference in age.

**SOIL ECOLOGY** - A broad concept of soil and its behavior in the total environment to include both living and nonliving factors and their interactions with soil.

**SOIL EROSION** - See erosion and erosion classes.

**SOIL EXTRACT** - The solution separated from a soil suspension or from a soil by filtration, centrifugation, suction, or pressure. (May or may not be heated prior to separation.)

**SOIL FAMILY** - In soil classification one of the categories intermediate between the great soil group and the soil series. Families provide groupings of soils with ranges in texture, mineralogy, temperature, and thickness. See soil classification.

**SOIL FLOW** - See solifluction.

**SOIL FORMING FACTORS** - Basically, the development of soil within a landscape in steps and stages as affected by time, topography, climate, minerals, organisms and other related factors.

**SOIL GEOMETRY** - See pore geometry.

**SOIL HORIZON** - A layer of soil or soil material approximately parallel to the land surface and differing from adjacent genetically related layers in physical, chemical and biological properties or characteristics such as color, structure, texture, consistency, kinds and number of organisms present, degree of acidity or alkalinity, etc. See soil master horizons and layers, genetic soil horizon.

**SOIL HORIZON SYMBOLS** - In soil survey, an indication of the direction of presumed pedogenesis (formation of soil structure), while diagnostic horizons indicate the magnitude of that expression. See diagnostic soil horizons.

**SOIL HYDROLOGY** - The science dealing with the distribution and movement of the soil solution in the soil profile.

**SOIL INFILTRATION** - The penetration of water or other liquids through the surface of the soil (ground) into the sub-surface soil. See soil water infiltration.

**SOIL INHIBITOR** - Any agent that interferes with soil processes, e.g., addition of toxic wastes to interfere with soil microbial metabolism.

**SOIL INTERGRADE** - A soil that possess moderately well-developed distinguishing characteristics of two or more genetically-related classification units. Also see transitional soil.

**SOIL INTERPRETATIONS** - Predictions of soil behavior in response to specific uses or management. These are based on inferences from soil characteristics and qualities (e.g., trafficability, erodibility, productivity, etc.). They are either qualitative or quantitative estimates or ratings of soil productivities, potentials, or limitations.

**SOIL INTRINSIC PERMEABILITY** - The permeability of a soil or other porous medium as a property of the medium only, independent of the density and viscosity of the fluid. Hydraulic conductivity  $K$  is inversely proportional to the viscosity  $\mu$  of the water. The constancy of the product  $K\mu$  is the basis for intrinsic permeability.

**SOIL KIND** - A soil with distinguishing characteristics. See soil type and soil map unit.

**SOIL LICHENS** - An association (symbiosis) of an algae and a fungus to form crustose, foliose, or fruticose bodies on the soil surface.

**SOIL LIQUID PHASE** - All the liquids and/or chemicals in the soil system. See soil water.

**SOIL MACROFAUNA (MACROBIOTA)** - Soil-inhabiting biota that generally include the larger insects, earthworms (Lumbricidae) and other organisms which can be easily sorted by hand; and commonly including burrowing vertebrates, such as moles, ground squirrels, pocket gophers, and reptiles such as tortoises and snakes, which affect soil structure.

**SOIL MAP** - A map showing the distribution of soil "types" or other soil mapping units in relation to the prominent physical and cultural features of the earth's surface, See American Society of Agronomy, 1987 Glossary of Soil Science Terms, for details on kinds of soil maps.

**SOIL MAP UNIT** - (i) A conceptual group of one to many delineations identified by the same name in a soil survey that represent similar landscape areas; (ii) A loose synonym for a delineation of soils. Also see soil "type," and soil series.

**SOIL MASTER HORIZONS AND LAYERS -**

**O horizons** - Layers dominated by organic material, except limnic layers that are organic.

**A horizons** - Mineral horizons that formed at the surface or below an O horizon and (i) are characterized by an accumulation of humified organic matter intimately mixed with the mineral fraction and not dominated by properties characteristic of E or B horizons; (ii) have properties resulting from cultivation, pasturing or similar kinds of disturbances.

**E horizons** - Mineral horizons in which the main feature is loss of silicate clay, iron, aluminum, or some combination of these, leaving a concentration of sand and silt particles of quartz or other resistant materials.

**B horizons** - Horizons that formed below an A, E, or O horizon and are dominated by (i) carbonates, gypsum, or silica, alone or in combination; (ii) evidence of removal of carbonates; (iii) concentrations of sesquioxides; (iv) alterations that form silicate clay; (v) formation of granular, blocky, or prismatic structure; or (vi) combination of these.

**C horizons** - Horizons or layers, excluding hard bedrock that are little affected by pedogenic processes and lack properties of O, A, E, or B horizons. Most are mineral layers, but limnic layers, whether organic or inorganic, are included.

**R layers** - Hard bedrock including granite, basalt, quartzite and indurated limestone or sandstone that is sufficiently coherent to make hand digging impractical.

See USDA Soil Survey Staff, 1990, Keys to Soil Taxonomy, SMSS Tech. Monogr. No. 19, and other soil taxonomy references for details.

**SOIL MECHANICAL ANALYSIS** - The separation of a soil into its content of clay, silt, and sand fractions (e.g., soil separates) by mechanical means, and the determination of the percentage of each group in a given sample, i.e., particle size analysis. See soil separates and particle size distribution.

**SOIL MESOFAUNA (MESOBIOTA)** - Soil-inhabiting animals smaller than soil macrobiota and larger than soil microbiota (microorganisms), including nematodes, small oligochaete worms (Enchytraeids), smaller insect larvae, and the microarthropods; of the latter, the soil mites (Acarina), and springtails (Collembola) are often the most abundant permanent soil inhabitants.

**SOIL METAL PERSISTENCE** - The length of time a metal species or compound will stay in a given soil matrix following the introduction of the metal into or onto the soil. Persistence can range from less than a second to indefinitely.

**SOIL MICROBIAL POPULATION** - The total number of living microorganisms in a given volume or mass of soil.

**SOIL MICROBIOLOGICAL PROPERTIES** - Those properties of the soil relating to soil-inhabiting microorganisms, their functions and activities, e.g., kinds and numbers of soil microflora and

microfauna, organic matter decomposition, transformation of hydrocarbons and various elements, biogeochemical cycles, etc.

**SOIL MICROBIOLOGY** - The branch of soil science concerned with soil-inhabiting microorganisms and their functions and activities.

**SOIL MICROBIOTA** - Generally, microscopic forms, such as soil algae, especially green and blue-green types and diatoms, autotrophic and heterotrophic, symbiotic and nonsymbiotic bacteria, fungi, actinomycetes, streptomycetes, protozoa, and myxomycetes. Viruses may be included, although they are submicroscopic in size. See microflora, microfauna, and mycorrhiza.

**SOIL MICROFAUNA** - See microfauna.

**SOIL MICROFLORA** - See microflora.

**SOIL MICROHABITAT** - The pores (voids) of various kinds within a soil in which bacteria, fungi and other microorganisms live. Also see microsite.

**SOIL MINERAL** - (i) Any mineral that occurs as a part of or in the soil. (ii) A natural inorganic compound with definite physical, chemical, and crystalline properties (within the limits of isomorphism) that occurs in the soil. See clay mineral.

**SOIL MINERAL FRACTION** - In general, the content of gravel, sand, silt, and clay.

**SOIL MINERALOGICAL PROPERTIES** - Characteristics, processes and reactions of a soil associated with soil minerals, and which can be described by, or expressed in, chemical and physical terms and equations. Included separately, or as chemical and physical properties of a soil. See soil chemical properties, soil physical properties, soil mineral, clay mineral, and phyllosilicate mineral.

**SOIL MOISTURE CONTENT** - See soil water (moisture) content.

**SOIL MOISTURE (WATER) POTENTIAL** - A measure of the difference in the free energy state of soil water and that of pure water. Technically defined as that amount of work that must be done per unit quantity of pure water in order to transport reversibly and isothermally an infinitesimal quantity of water from a pool of pure water, at a specified elevation and at atmospheric pressure, to the soil water (at the point under consideration). See soil water. Also see Soil Science Society of America, 1987, Glossary of Soil Science Terms, for additional details.

**SOIL MOISTURE (WATER) REGIMES** - The presence or absence either of ground water or water held at a tension less than 1500 kPa (< 15 bar moisture or water tension, near permanent wilting point) in the soil or in specific horizons by periods of the year. Water held at a tension of 1500 kPa or more is not available to keep most mesophytic plants alive. The availability of water also is affected by

dissolved salts. Soil moisture status over a period of time can be relegated to soil temperature regimes in particular climatic zones, e.g., an aridic and torric (hot and dry) soil moisture regime.

**SOIL MORPHOLOGY** - (i) The physical constitution, particularly, the structural properties, of a soil profile as exhibited by the kinds, thickness, and arrangement of the horizons in the profile, and by the texture, structure, consistency, and porosity of each horizon. (ii) The structural characteristics of the soil or any of its parts. See soil structure.

**SOIL NAME** - The basic name of the predominant constituent and a single-word modifier indicating the major subordinate constituent.

**SOIL NUTRIENT DIFFUSION** - The movement of nutrients in soil or pedon as a result of a concentration gradient.

**SOIL NUTRIENT** - See macronutrients and micronutrients.

**SOIL ORDER** - A category within the schema of soil classification based upon soil-forming processes as indicated by the presence or absence of major diagnostic horizons. See soil diagnostic horizons.

**SOIL ORGANIC RESIDUE** - Animal and vegetative materials added to the soil and which are recognizable as to their origin.

**SOIL PARAMETER** - A specific soil measurement or property, especially one that can be quantified. See soil properties.

**SOIL PERMEABILITY** - (i) The rate at which water or other liquids pass through soil in a specified direction, usually by gravitational flow; (ii) The ease with which gases, liquids, or plant roots penetrate or pass through a bulk mass of soil or a layer of soil. Since different soil horizons vary in permeability, the particular horizon under question should be designated. (iii) The property of a porous medium itself that expresses the ease with which gases, liquids, or other substances can flow through it, and is the same as intrinsic permeability  $k$ . See Darcy's law and soil water.

**SOIL pH** - See soil reaction.

**SOIL PHYSICAL PROPERTIES** - Those characteristics, processes, or reactions of a soil which are caused by physical forces and which can be described by, or expressed in, physical terms or equations. Sometimes confused with and difficult to separate from chemical properties; hence, the terms *physic&chemical* or *physicochemical*. Examples of physical properties are bulk density, water-holding capacity, hydraulic conductivity, porosity, pore-size distribution, etc.

**SOIL PHYSICS** - The branch of soil science that deals with the physical properties of the soil, with emphasis on the state and transport of matter (especially water) and energy in the soil.



**SOIL PLASMA** - That part of the soil material that is capable of being or has been moved, reorganized, and/or concentrated by the processes of soil formation. It includes all the material, mineral or organic, of colloidal size and relatively soluble material that is not contained in the skeleton grains. See soil forming factors, minerals, organic matter, colloids.

**SOIL POISE** - See poised soil system.

**SOIL POLLUTANT IMMOBILIZATION** - In a contaminated soil environment, the irreversible sorption of pollutants, thus preventing leaching. Compare with immobilization.

**SOIL POLLUTION** - Deterioration of the quality of the soil as determined by various soil characteristics that are affected by the addition of impurities, e.g., waste substances and materials.

**SOIL POPULATION** - (i) All the organisms living in the soil, including plants and animals. (ii) Members of the same taxa. (iii) Delineations of the same map unit - a grouping of like things in a statistical sense. See soil map unit.

**SOIL PORE GEOMETRY** - See pore geometry.

**SOIL PORES** - That part of the bulk volume of soil not occupied by soil particles. Soil pores have also been referred to as interstices or voids.

**SOIL PROFILE** - A vertical section of the soil through all its horizons and extending into the parent material. An excavated soil exposes the soil profile.

**SOIL PROPERTIES** - See soil characteristics. (Sometimes considered to be more definitive and quantitative than general soil characteristics.)

**SOIL QUALITIES** - Inherent attributes of soils which are inferred from soil characteristics or indirect observations, e.g., compactibility, erodibility or fertility. See soil characteristics.

**SOIL QUALITY** - The characteristics or properties identified for a soil, depending upon its intended use or purpose, and an assessment of the soil for that particular use or purpose, e.g., a soil having unfavorable characteristics for plant growth is a soil of poor quality.

**SOIL REACTION (pH)** - The degree of acidity or alkalinity of a soil, usually expressed as a pH value, and ranging from extremely acid, pH < 4.5, through very strongly alkaline, pH > 9.1. Soil pH is the negative logarithm of the hydrogen ion activity, usually of a soil solution or paste.

**SOIL REDOX POTENTIAL (Eh)** - The ratio of reduced to oxidized substances in a soil. A measurement of redox potential can give a reliable measurement of soil aeration. See redox potential and aerated soil.

**SOIL SAMPLE** - A portion of the soil mass taken for the purpose of estimating certain soil characteristics or parameters, either for field or laboratory analysis. See sample, Superfund.

**SOIL SATURATION POINT** - That point at which water or chemicals completely saturate the soil and fill the pores. See saturated soil, saturation extract.

**SOIL SCIENCE** - That science dealing with soils as a natural resource on the surface of the earth including soil formation, classification and mapping, and physical, chemical, biological, and fertility properties of soils per se; and these properties in relation to their use and management. Edaphology deals with the influence of the soils on living things. Pedology mainly considers soil as a biochemical product of nature.

**SOIL SEPARATES** - Mineral particles, < 2.0 mm in equivalent diameter, ranging between specified size limits. The names and size limits of separates recognized in the United States are: very coarse *sand*, 2.0 to 1.0 mm; *coarse sand*, 1.0 to 0.5 mm; *medium sand*, 0.5 to 0.25 mm; *fine sand*, 0.25 to 0.10 mm; *very fine sand*, 0.10 to 0.05 mm; *silt*, 0.05 to 0.002 mm; and *clay*, < 0.002 mm. The separates recognized by the International Society of Soil Science are: I) *coarse sand*, 2.0 to 0.2 mm; II) *fine sand*, 0.2 to 0.02 mm; III) *silt*, 0.02 to 0.002 mm; and IV) *clay*, < 0.002 mm.

**SOIL SERIES** - The lowest category of US. system of soil taxonomy; a conceptualized class of soil bodies (polypedons) that have limits and ranges more restrictive than all higher taxa. Soil series are commonly used to name dominant or codominant polypedons represented on detailed soil maps. The soil series serve as a major vehicle to transfer soil information and research knowledge from one soil area to another. See polypedon and soil map.

**SOIL SOLID PHASE** - All of the soil solid particles in the soil system. See soil separates.

**SOIL SOLIDS** - See soil solid phase, soil separates, void ratio.

**SOIL SOLUTES** - The chemical substances, micronutrients, macronutrients, or contaminants dissolved in the soil solution or liquid phase. See soil solution.

**SOIL SOLUTION** - The liquid phase of a soil, i.e., that part of the soil system not occupied by mineral particles or soil air. It usually consists of water, soluble salts, and other materials, e.g., humus particles, suspended in it.

**SOIL SPATIAL VARIABILITY** - The variation in soil properties (1) laterally across the landscape, at a given depth, or with a given horizon, or (2) vertically downward through the soil.

**SOIL STRATA** - Soil arranged in or composed of strata or layers. Soil layers may be applied to cover reclamation sites, waste sites and materials.

**SOIL STRUCTURE** - The combination or arrangement of primary soil particles into secondary particles, units, or peds. See structure classes, grades, and types.

**SOIL SUBORDINATE DISTINCTIONS** - In soil survey, 22 subordinate distinctions and characteristics are recognized within master horizons and layers and are used to further characterize master horizons and layers. See soil master horizons and layers.

**SOIL SURFACE** - See surface soil.

**SOIL SURFACE SEAL** - The presence of a compacted or hydrophobic layer on the surface of the soil that reduces water (or other liquid) infiltration.

**SOIL SURVEY** - The systematic examination, description, classification, and mapping of soils in an area. Soil surveys are classified according to the kind and intensity of field examinations and certain soil analyses.

**SOIL TAXONOMIC CLASSES** - In the context of soil survey, a class used in the system of soil classification or taxonomy. Diagnostic horizons and properties are used to identify the eleven classes (orders) of a soil. For details, see US EPA, 1990, Keys to Soil Taxonomy, SMSS Tech. Monogr. No. 19, and other soil taxonomy references.

**SOIL TAXONOMY** - The science of classifying soils. See soil survey.

**SOIL TEMPERATURE** - See temperature (soil).

**SOIL TEST** - A chemical, physical or biological procedure which estimates a property of the soil pertinent in the agricultural sense usually to the suitability of the soil to support plant growth.

**SOIL TEXTURE** - Relative proportions of the various sizes of mineral particles (gravel, sand, silt, clay) in a soil.

**SOIL TEXTURE BY "FEEL"** - See sticky point.

**SOIL TEXTURE CLASSES** - The relative proportions of the various soil separates (mineral particles of sand, silt, and clay < 2.0 mm in diameter), and described into textural classes on the basis of the proportions of the various separates present. See soil separates.

**SOIL "TYPE"** - (Note: obsolete) Formerly in the U.S. soil classification systems prior to publication USDA *Soil Taxonomy* (1975). (i) The lowest unit in the natural system of soil classification; a subdivision of a soil series and consisting of or describing soils that are alike in all characteristics including the texture of the A horizon or plow layer, (ii) In Europe, roughly equivalent to a great soil group. (iii) A kind of soil, as used popularly in nonsoil literature and technical documents. See soil series and soil map unit.

**SOIL VOIDS** - See soil pores.

**SOIL WASHING OR FLUSHING** - For RCRA corrective action, excavated soil is flushed with water or other solvents to leach out contaminants; used for organic wastes and certain soluble inorganic wastes.

**SOIL WASTE MANAGEMENT UNIT** - Any unit in which wastes have been placed at any time, regardless of whether the unit was designed to accept solid or hazardous waste. Units include areas from which solid wastes have been routinely released.

**SOIL WATER BUDGET** - The amount of measurable water in the soil system or profile over a specified period of time.

**SOIL WATER (MOISTURE)** - Water in soil is subject to several force fields originating from the presence of the soil solid phase; the dissolved salts; the action of external gas pressure; and the gravitational field. These effects may be quantitatively expressed by assigning an individual component potential to each. The sum of these potentials is designated the total potential of soil water. See soil water total potential, and soil moisture (water) content. Also see Soil Science Society of America, 1987, Glossary of Soil Science Terms, for additional details.

**SOIL WATER (MOISTURE) CONTENT** - The water lost from the soil upon drying to constant mass at 105 °C; and expressed either as the mass of water per unit mass of dry soil or as the volume of water per unit bulk volume of soil. (Constant weight is usually obtained after 24 hrs.)

**SOIL WATER DIFFUSIVITY** - The hydraulic conductivity divided by the differential water capacity (care being taken to be consistent with units), or the flux of water per unit gradient of moisture content in the absence of other force fields.

**SOIL WATER INFILTRATION** - The downward entry (penetration) of water into the soil through the soil surface. See infiltration.

**SOIL WATER MATRIC POTENTIAL** - The amount of work that must be done per unit quantity of pure water in order to transport reversibly and isothermally an infinitesimal quantity of water, identical in composition to the soil water, from a pool at the elevation and the external gas pressure of the point under consideration, to the soil water.

**SOIL WATER PERCOLATION** - The downward movement of water through the soil, especially in saturated or nearly saturated soil at hydraulic gradients of the order of 1.0 or less. See hydraulic gradient, hydraulic conductivity and Darcy's law.

**SOIL WATER PRESSURE** - The pressure (positive or negative), relative to the external gas pressure on the soil water, to which a solution identical in composition to the soil water must be subjected in order to be in equilibrium through a porous permeable wall with the soil water.

**SOIL WATER SORPTIVITY** - In hydraulic conductivity of unsaturated soils the cumulative infiltration,  $I$ , into a soil column having uniform time,  $t$ ; i.e.,  $I = ST^{\frac{1}{2}}$ . The coefficient of proportionality,  $S$ , varies with water content and differs between soils and is termed *sorptivity*.

**SOIL WATER TOTAL POTENTIAL** - The mechanical work required to transfer unit quantity of water from a standard reference point to a given situation in the soil. Referred to unit weight of water, it has the dimension of length and is known as *suction head*.

**SOLAR RADIATION, INCOMING** - Also referred to as “insolation,” the total electromagnetic radiation emitted by the sun and falling on the earth. Data can usually be directly related to atmospheric stability. Models to compute rates of chemical volatilization or vaporization may use solar radiation data quantitatively.

**SOLID WASTE** - A variety of discarded, degradable, and nondegradable wastes, not generally toxic or hazardous, resulting from industrial, municipal, agricultural, home and institutional sources, usually deposited in open dumps or sanitary landfills. Nontoxic and nonhazardous mining wastes may be included.

**SOLID WASTE DISPOSAL ACT (SWDA)** - This Act was amended in 1986 by The Resource Conservation and Recovery Act (RCRA). SWDA has since been amended by several public laws, including the Used Oil Recycling Act of 1980 (UORA), the Hazardous and Solid Waste Amendments of 1984 (HSWA), and the Medical Waste Tracking Act of 1988 (MWTa). See RCRA.

**SOLID WASTE DISPOSAL** - The final placement of waste refuse that is not salvaged or recycled.

**SOLID WASTE MANAGEMENT** - Supervised handling of waste materials from their source through recovery processes to disposal.

**SOLID WASTE, Superfund** - Any solid, semisolid, liquid, or contained gaseous material present in wastes.

**SOLID WASTE TOXICITY** - An extraction procedure (EP) developed by EPA to simulate waste leachate in sanitary landfills. The extract is analyzed for the presence of eight specific elements and six specific organic compounds (pesticides) to determine if thresholds are exceeded. The EP extract should not contain elements or compounds equal to or greater than designated concentrations. If any of the limits are exceeded, the waste has the characteristic of EP toxicity and is classified as a hazardous waste. See hazardous waste.

**SOLIFLUCTION** - The slow (normally 0.5 to 5.0 cm/year) viscous, downslope flow of waterlogged soil and other saturated surficial material.

**SOLUM** - (plural: SOLA) The upper and most weathered part of the soil profile; the A, E, and B horizons. See soil master horizons and layers.

**SOLUTE** - The component of a solution, e.g., soil metal, ion or organic substance, usually present in the smaller amount.

**SOLVENT** - The component of a solution usually present in the larger amount.

**SORPTION** - (i) The action of soaking up or attracting substances; a process used in many pollution control systems; (ii) A physical/chemical process in which the increase of solute concentration evolves at the soil-water interface. See adsorption and absorption.

**SORPTIVITY** - See soil water sorptivity.

**SOURCE CONCENTRATION** - The concentration of a contaminant in the soil of a site (i.e., the source of ground water contamination).

**SPECIAL WASTE** - (i) Waste materials that occur in very large volumes, but with low potential hazard; generally not amenable to management techniques developed for hazardous waste; (ii) Waste streams that do not come under RCRA purview, but are considered hazardous. Examples of regulated materials include oil waste, in specific states spent lead acid batteries, and PCBs and asbestos which are considered hazardous under the Toxic Substances Control Act (TSCA).

**SPECIES** - A reproductively isolated aggregate of interbreeding populations of organisms.

**SPECIFIC HAZARDOUS WASTE SOURCES** - Waste generated during the manufacturing processes of certain industries: inorganic pigments; inorganic chemicals; organic chemicals; wood preservatives; pesticides; petroleum refining; iron, steel, and secondary lead smelting; coking; ink formulation; and veterinary pharmaceuticals.

**SPILL** - Any unplanned or accidental discharge (event), release, dumping, emitting, emptying, and pumping of hazardous waste onto or in land (soil), air, or water, and which is denoted as hazardous.

**SPILL PREVENTION CONTROL AND COUNTERMEASURES PLAN** - A plan covering the release of hazardous substances as defined in the Clean Water Act.

**SPOIL** - Soil (dirt) or rock removed from its original location, thereby destroying the inherent nature of the soil in the process of removal.

**STAGING AREA** - A section of a site with adequate control (e.g., paved and drained runoff prohibited) for the safe storage and handling of drummed waste or other hazardous materials.

**STANDARD MEDIUM** - Any culture medium commonly used to grow and enumerate microorganisms.

**STICKY POINT (OF A SOIL)** - The point at which a moistened sample of soil can be worked easily between the fingers, but has no tendency to run or flow. Soil at this moisture content is used to help

determine the texture by “feel” in the field rather than by mechanical analysis in the laboratory. Also see soil mechanical analysis.

**STORAGE** - Temporary holding of waste pending treatment or disposal. Storage methods include containers, tanks, waste piles, and surface impoundments.

**STREPTOMYCETES** - A group of microorganisms usually classified as a family, Streptomycetaceae, within the Actinomycetes. Microorganisms are found with vegetative mycelium found in bacillary or coccoid forms; a member of the genus *Streptomyces*. See microfauna and actinomycetes.

**STRONG GLEYED SOIL** - Soils that either have iron that has been reduced and removed during soil formation or that saturation with stagnant water has preserved a reduced state. Most of the affected layers have low chroma and many are mottled. See gleyed soil, mottle and color, chroma.

**STRUCTURE CLASSES** - A grouping of soil structural units or peds on the basis of size.

**STRUCTURE GRADES** - A grouping or classification of soil structure (the combination or arrangement of primary soil particles into secondary particles, units, or peds) on the basis of inter- and intra-aggregate adhesion, cohesion, or stability within the profile.

**STRUCTURE TYPES** - A classification of soil structure based on the shape of the aggregates or peds and their arrangement in the profile.

**SUBSIDENCE** - The lowering of the natural land surface in response to natural, artificial, or induced causes.

**SUBSOIL** - The soil found in nature beneath the topsoil, usually less modified by soil-forming factors and containing less humus, soil nutrients, and microorganisms, and other distinctive soil properties.

**SUBSTRATUM** - Any layer lying beneath the soil solum, either conforming or unconforming.

**SUCTION HEAD** - See soil water matric potential.

**SUPERFUND** - The program operated under the legislative authority of CERCLA and SARA that funds and carries out the EPA solid waste emergency and long-term removal remedial activities. These activities include establishing the National Priorities List, investigating sites for inclusion on the list, determining their priority level on the list, and conducting and/or supervising the ultimately determined cleanup and other remedial actions. See CERCLA and SARA.

**SURFACE** - The exterior or outside part of the solid or liquid Earth.

**SURFACE DRAINAGE** - (i) The removal of excess water from the surface of the soil. (ii) Used to refer to surface movement of excess water. Includes such terms as ponded, flooded, slow, and rapid.

**SURFACE EROSION AND ERODIBILITY** - Erosion: wearing away of the soil or land surface by running water, wind, ice, or other geological agents, including such processes as gravitational creep. Erodibility: the vulnerability or degree of susceptibility of soil to erosion processes.

**SURFACE FEATURES** - Conspicuous features on the soil surface that may be examined and described, including not only natural features, but distinct artificial features introduced through human activities.

**SURFACE HYDROLOGY** - The science dealing with the distribution and conveyance of water on the soil surface.

**SURFACE IMPOUNDMENT** - A natural topographic depression, manmade excavation or diked area, usually formed of earthen materials or lined with manmade materials, designed to contain liquids, or wastes containing free liquids, See hazardous waste surface impoundment, pit, pond, lagoon.

**SURFACE IMPOUNDMENT HAZARDS** - Potential hazards from impoundments including leakage of hazardous substances to the surrounding soil, underlying vadose (unsaturated) zone, and especially to ground water; and, gaseous emissions of volatile materials,

**SURFACE LAYER** - See surface soil.

**SURFACE POLLUTION SITUATIONS** - Contamination of the soil with various harmful compounds and materials primarily introduced by human activities, e.g., metals in waste materials.

**SURFACE RUNOFF** - That portion of the meteoric precipitation on an area of soil or land surface which is discharged from the area through natural or manmade stream channels.

**SURFACE SOIL** - The uppermost part of the soil, considered in agriculture as that ordinarily moved in tillage, or its equivalent in uncultivated soils, and ranging in depth from 7-20 cm. Frequently designated as the "surface layer," ("Ap layer," or the "Ap horizon"). Also see tillage.

**SURFACE TIER** - The surface tier is the upper 60 cm (24 in.) if (1) the soil material is fibric and three-fourths or more of the fiber volume is derived from *Sphagnum* or mosses, or (2) the material has a bulk density less than 0.1; otherwise, the surface tier is the top 30 cm (12 in.) exclusive of loose surface litter or living mosses, See fibric soil material.

**SURFACE WATER** - All waters on the face of the Earth, including fresh and salt water, ice and snow. Soil water is not included.

**SURFICIAL** - Pertaining to, situated at, formed or occurring on a surface.

**SURFICIAL CREEP** - See soil creep.



**SURFICIAL AND BEDROCK GEOLOGY** - The surficial geology of a region is usually contrasted with or studied separately from the bedrock geology. Surficial usually refers to the unconsolidated materials (overburden) such as the glacial sediments, alluvium, or soil. Also see bedrock.

**SWAMP** - An area saturated with water throughout much of the year but with the surface of the soil usually not deeply submerged. Usually characterized by tree or shrub vegetation. See marsh and miscellaneous areas.

**TAILINGS** - By-products of mining and milling; residues of raw materials or waste separated during the processing of mineral ores or crops.

**TARDIGRADES** - Any of a division Tardigrada of microscopic arthropods that have four pairs of legs and usually live in water or damp moss. Also found in soil moss-lichen habitats. See arthropod.

**TAXONOMY** - The systematic distinguishing, classification, and naming of type groups within a specified subject field. See soil taxonomy and soil survey.

**TEMPERATURE (SOIL)** - The degree of heat of a given body of soil at a particular point in time and space or during a particular period of time and a particular depth or surface extent of soil; usually determined in °F or °C.

**TEMPERATURE GRADIENT** - The rate of decrease of air, water, or soil temperature with distance, usually in the direction it decreases most rapidly. Temperature gradients may be encountered at waste sites depending on the nature and concentration of contaminants, the period of time of contamination, and rate of degradation.

**TEMPERATURE REGIMES OF SOIL** - The pattern of soil temperature fluctuations in a soil, characterized by temperature distribution with respect to depth, time, and season for a given soil at a given location. See knowledge frames for values: perigelic, cryic, frigid-isofrigid, mesic-isomesic, thermic-isothermic, and hyperthermic-isohyperthermic.

**TENSIOMETER** - A device for measuring the soil-water matric potential (or tension, or suction) of water in soil in situ; a porous, permeable ceramic cup connected through a water-filled tube to a manometer, vacuum gauge, pressure transducer, or other pressure measuring device. See hydraulic head and piezometer.

**TERRACING** - Diking, built along the contour of sloping agricultural land, that holds runoff and sediment to reduce erosion.

**TEXTURE CLASSES** - The relative proportions of the various soil separates (mineral particles of sand, silt, and clay < 2.0 mm diameter) and described into textural classes on the basis of the proportions of the various separates present. Contrast particle-size classes.

**THERMAL POLLUTION** - A change in the quality of an environment due to induced substances or materials causing a raise in temperature.

**THERMODYNAMICS** - The branch of physics that seeks to derive, from a few basic postulates, relationships between properties of matter, especially those affected by changes in temperature, and a description of the conversion of energy from one form to another. Thermodynamics are important in soil processes such as water potential, solute movement and exchange, etc. Also see ion activity.

**THRESHOLD LIMIT VALUE** - Representations of the air concentrations of chemical substances to which it is believed that workers may be exposed daily without adverse effect.

**TIGHT SOIL** - A compact and relatively impervious and tenacious soil (or subsoil) which may or may not be plastic (capable of being molded or transformed). Also see plastic soil.

**TILLAGE** - The mechanical manipulation of soil; in the agricultural sense, the modification of soil conditions for successful crop production.

**TILTH** - The physical condition of a soil in relation to ease of tillage (cultivating) and plant growth. See tillage.

**TOLERANCE** - The capacity of an organism to live under a given set of conditions within its range of ecological amplitude. See ecological amplitude.

**TOLERANCES, pesticides** - The permissible residue levels for pesticides in raw agricultural produce and processed foods. Tolerance levels are established by EPA and enforced by FCA and USDA.

**TOPOGRAPHIC MAPS** - A map showing the relief of the land surface by means of contour lines.

**TOPOGRAPHY** - The physical features of a surface area including relative elevations and the position of natural and man-made features.

**TOPSOIL** - The surface layer of soil commonly moved during cultivation, usually containing humus; because of presumable fertility, it is applied to topdress landfills, waste sites, and roadbanks, etc.; usually capable of supporting plant growth. See tillage.

**TORTUOSITY** - (i) The average ratio of the actual roundabout path to the apparent or straight flow path (in a soil). See soil geometry, hydraulic conductivity. (ii) The nonlinear nature of soil pores.

**TOXICANT** - A poisonous agent that kills or injures animal or plant life.

**TOXIC POLLUTANTS** - Materials contaminating the environment that cause death, disease, and/or birth defects in organisms that ingest or absorb them. The quantities and length of exposure necessary to cause these effects can vary widely.

**TOXIC SUBSTANCE** - A chemical or mixture that may present an unreasonable risk of injury to health or the environment.

**TOXIC WASTE** - Any waste or substance whose physiological action is harmful to human or animal health or the environment.

**TOXICITY** - The degree of danger posed by a substance to animal or plant life. (May be described as acute or chronic toxicity.)

**TOXICITY CHARACTERISTIC (TC) RULE** - This rule replaces the Extraction Procedure (EP) toxicity test with the TC test to determine whether or not a waste is a characteristic waste based on toxicity. The new TC test requires analysis of 25 organic compounds in addition to the eight metals and six pesticides that were subject to the EP test. See also toxicity characteristic leaching procedure.

**TOXICITY CHARACTERISTIC LEACHING PROCEDURE (TCLP)** - The analytical method one must use to determine whether or not a waste is a characteristic hazardous waste based on toxicity. The TCLP is also necessary to comply with provisions of land disposal restrictions as well. See also toxicity characteristic rule.

**TOXICITY TEST EXTRACTION PROCEDURES** - An EPA toxicity test used to define hazardous wastes. See solid waste toxicity.

**TRAFFICABILITY** - The quality of the terrain or site to permit passage, as of vehicles or personnel.

**TRANSITIONAL HORIZONS** - Soil horizons that are transitional or gradients between soil master horizons and layers. There are two kinds of transitional horizons. In one, the properties of an underlying or overlying horizon are superimposed on properties of the other horizon throughout the transition zone. In the other, parts that are characteristic of an overlying or underlying horizon are enclosed by parts that are characteristic of the other horizon. Special conventions are used to designate these kinds of horizons. Also see soil master horizons and gradients and USDA, 1990, Keys to Soil Taxonomy, SMSS Tech. Monogr. No. 19, or other soil taxonomy references, for details.

**TRANSITIONAL SOIL** - A soil that possesses properties and distinguishing characteristics of two or more soils; soil intergrades. Compare with transitional horizons.

**TRANSPORT RATES** - The rate of movement of a contaminant in a natural transport medium such as soil or ground water, either as solid particles or in solution, from one place to another.

**TRANSPORTED SOIL** - Soil materials and soil parent material moved usually by various natural agencies, gravity, water, ice and wind.

**TRANSURANIC WASTE** - Waste that contains manmade elements heavier than uranium; includes those having an atomic number greater than that of uranium, i.e., greater than 92. Most transuranic

waste results from reprocessing nuclear fuel. Disposal is similar to high-level waste because of its long decay period. See high-level radioactive waste.

**TREATMENT, STORAGE, AND DISPOSAL (TSD) FACILITY** - The site where a hazardous substance is treated, stored, or disposed. TSD facilities are regulated by EPA and states under RCRA.

**TRUNCATED SOIL** - A soil having lost all or part of the upper soil horizon or horizons. Naturally-formed soils or disturbed soils may be truncated.

**TURBELLARIANS** - Any of a class Turbellaria of mostly aquatic and free-living flat worms, but also inhabiting moist soil, especially small Turbellaria. See soil mesofauna.

**UNCONTROLLED HAZARDOUS WASTE DISPOSAL SITES** - Refers to a site where hazardous wastes have been disposed or spilled in such a way as to pose a threat to human welfare or the environment. Also call abandoned or inactive hazardous waste sites.

**UNDERGROUND RUNOFF (SEEPAGE)** - Water that seeps toward stream channels after infiltration into the ground.

**UNDERGROUND STORAGE TANK (UST)** - (i) A tank located all or partially underground that is designed to hold gasoline or other petroleum products or chemical solutions. (ii) One or more tanks, including underground connective piping, that store “regulated substances” and that are more than 10 percent below the surface of the ground. Regulated substances include hazardous chemical products regulated under CERCLA and petroleum products. USTs are regulated under Subtitle I of RCRA; however, underground tanks containing hazardous wastes continue to be regulated under Subtitle C of RCRA.

**UNIVERSAL SOIL LOSS EQUATION (USLE)** - An equation for predicting  $A$ , the average annual soil loss in mass per unit area per year, and is defined as  $A = RKLSPC$ , where  $R$  is the rainfall factor,  $K$  is the soil erodibility factor,  $L$  is the length of slope,  $S$  is the percent slope,  $P$  is the conservation practice factor, and  $C$  is the cropping and management factor.

**UNPRODUCTIVE SOIL** - A soil in which the chemical, physical, and biological conditions are unfavorable for the economic production of crops suited to a particular area.

**UNSATURATED FLOW** - The movement of water in soil in which the pores are not completely filled with water. See hydraulic conductivity, unsaturated.

**UNSATURATED ZONE** - (i) The zone or layer of aerated soil; pore space is not filled with water or other liquids; (ii) The area above the water table where the soil pores are not fully saturated, although some water may be present. Also called the vadose zone.

**UNSATURATED ZONE THICKNESS** - The width of the zone between the land surface and the water table, including the root zone, intermediate zone, and capillary fringe. Value usually obtained by drilling and analyzing soil cores at various site locations. Also see saturated zone thickness.

**URBAN LAND** - Areas so altered or obstructed by urban works or structures that identification of soils is not feasible. (Considered by Soil Science Society of America Glossary as a miscellaneous area.)

**URBAN RUNOFF** - Storm water from city streets and adjacent domestic or commercial properties that may carry pollutants of various kinds into the sewer systems and/or receiving waters,

**VADOSE WATER** - See water table, perched.

**VADOSE ZONE** - The region or depth extending from the approximate ground surface to the upper surface of the principal water-bearing formation, See unsaturated zone.

**VALENCE** - (i) The relative ability of a substance to react or combine. (ii) A positive number that characterizes the combining power of an element for other elements.

**VAPOR PRESSURE** - The pressure exerted by the vapor over a liquid once evaporation and condensation have come to equilibrium.

**VAPORIZATION** - The escape of molecules from liquid or solid phase to the gas phase, e.g., release of water (and solutes) from the aqueous soil phase to the gaseous phase.

**VEGETATION** - The nature, kind, extent, and distribution of plants and plant cover for a given, designated site. Also see ground cover.

**VIRUS** - The smallest form of microorganisms capable of causing disease. Sometimes included with the soil microbiota, although submicroscopic in size. Also see soil microbiota.

**VISCOSITY** - The resistance of a liquid to flow, e.g., a soil solution saturated with organics is more resistant to flow (more viscous) than an unsaturated solution.

**VISUAL OBSERVATIONS, Superfund** - Observations, usually performed by an Initial Entry Team, that would help in evaluating site hazards. Some examples are dead plants, dead fish or other animals; land features; wind direction; labels on containers indicating explosive, flammable, toxic or corrosive materials; conditions conducive to splash or contact with unconfined liquids, sludges, or solids, and other general conditions.

**VOID RATIO** - The ratio of the volume of soil pore (or void) space to the solid-particle volume.

**VOIDS** - See soil pores.

**VOLATILE CONTAMINANTS** - Chemicals characterized by low boiling points and high vapor pressures.

**VOCA** - See volatile organic compounds.

**VOLATILE ORGANIC COMPOUNDS (VOCA)** - (i) Any organic compound that participates in atmospheric photochemical reactions, except those designated by the EPA Administrator as having negligible reactivity. (ii) Those organic compounds amenable to analysis by the purge and trap technique; also called purgable compounds. See CLP (and also refer to its Statement of Work), and organic chemical/compounds.

**VOLATILIZATION** - The conversion of a chemical substance from a liquid or solid state to a gaseous or vapor state by the application of heat, by reduction of pressure, or a combination of both. Also called vaporization.

**VULNERABLE ZONE** - An area over which the airborne concentration of a chemical involved in an accidental release could reach the level of concern.

**WASTE** - A variety of unwanted materials resulting from industrial, commercial, mining, or agriculture operations and processes, and places of human or animal origin; can be any solid, liquid, semisolid, or contained gaseous materials or substance resulting from production of chemicals.

**WASTE ACCUMULATION** - The progressive increase in the content of waste substances or agents in organisms or media through successive or continuous deposit, ingestion, secretion or exposure, and its retention because of insufficient removal or elimination.

**WASTE CHARACTERISTIC** - Any one of the four categories used in defining hazardous waste: ignitability, corrosivity, reactivity, and toxicity.

**WASTE CHARACTERIZATION** - For a RCPA Part B Permit Application, information is needed that includes a waste inventory and characterization (types, volumes, and physical, chemical and biological characteristics); sampling and analysis of waste streams for hazardous constituents; background data and documentation if wastes are to be "delisted," and the waste analysis plan.

**WASTE CONCENTRATION** - The result of the process of waste accumulation; the accumulated content in proportion to the total mass of the receiving media or organism (See waste accumulation.)

**WASTE DESCRIPTION** - A description of the contamination at the site, including kinds of contamination; concentrations and distribution of contaminants, and environmental medium contaminated at the site.

**WASTE DISPOSAL SITE SAFEGUARDS** - Methods or means used to minimize harmful environmental effects at disposal sites: synthetic liners, leachate detection systems, runoff controls, and ground water monitoring systems.

**WASTE LAND** - Land not generally suitable for or capable of producing materials or services of value. Usually defined within an agricultural use context.

**WASTE MANAGEMENT** - The systematic control of the collection, source separation, storage, transportation, processing, treatment, recovery and disposal of hazardous waste.

**WASTE MATERIALS** - Waste matter of any kind or description, including, but not limited to solid waste, semisolid and liquid waste, garbage, sludge, munitions; radiological, chemical and warfare agents; radioactive materials, chemicals, biologicals, laboratory, surgical and institutional materials; industrial, commercial, mining, municipal, agricultural, and other wastes including discarded equipment and excavation debris.

**WASTE MINIMIZATION, Superfund** - Introduced in the 1984 Hazardous and Solid Waste Amendments (HSWA) to RCRA as a method of pollution prevention. It focuses on reducing hazardous waste generation and output at the source to avoid subsequent handling, treatment and disposal.

**WASTE PILE** - (i) Any noncontainerized accumulation of solid, nonflowing hazardous waste that is used for treatment or storage; (ii) Temporary storage of any solid waste.

**WASTE SITE** - An area or location in which wastes are deposited. See waste and site.

**WASTE SITE DISPOSAL METHODS** - Underground storage tanks (USTs), deep-well injection, land treatment, recycling and reuse (resource recovery), and “midnight dumping” - an illegal and unsafe method of disposal.

**WASTE STABILIZATION AND SOLIDIFICATION** - Waste mixed with agents that physically immobilize or chemically precipitate constituents for RCRA corrective action; applied primarily to metals and with mixed results when used to treat organics.

**WASTE STORAGE** - The holding of hazardous waste for a temporary period, at the end of which the hazardous waste is treated, disposed of, or stored elsewhere. Facilities are required to have a RCRA permit for storage of hazardous waste for more than 90 days does not require a RCRA permit.

**WASTE SUBSTANCE** - (i) Waste matter of particles of definite chemical composition; (ii) Physical material from which a waste is made. See waste materials.

**WASTE TREATMENT** - Any method, technique, or process that is applied to a waste after the waste has been generated, for the purposes of rendering it less hazardous.

**WASTEWATER** - The spent or used water which carries dissolved or suspended solids from industry, commercial enterprises, agriculture, farms, homes, and urban areas. See liquid waste.

**WATER POLLUTION** - The addition to water of any material or substance which alters the physical, chemical, or biological properties of the water and renders it less acceptable for use, e.g., soil water pollution.

**WATER-STABLE AGGREGATE** - A soil aggregate that is stable to the action of water, e.g., rainfall, or -agitation, as in wet sieve analysis, a mechanical analysis of soil.

**WATER RIGHTS** - Laws and regulations concerning the use of water, usually for irrigation purposes.

**WATER TABLE** - The upper surface of ground water or that level in the ground where the water is at atmospheric pressure.

**WATER TABLE, PERCHED** - The water table of a saturated layer of soil which is separated from an underlying saturated layer by an unsaturated layer (vadose water).

**WEATHER** - See climate and weather.

**WEATHERING** - All physical and chemical changes produced in rocks, at or near the earth's surface, by atmospheric agents.

**WETLAND** - An area of land that has hydric soils and hydrophytic vegetation. See hydric soils.

**WET SIEVE ANALYSIS** - A method used to determine soil aggregate size and stability; the primary factor governing the wet stability of aggregates is generally the method of wetting.

**WETTING ZONE** - A zone in soil following infiltration of water (or chemical) in which soil wetness decreases with depth and at a steeping gradient down to a discernible wetting front boundary between wet and dry soil.

**WILTING POINT** - See permanent wilting point.

**WIND** - The natural and relatively horizontal movement of air.

**WIND SPEED AND DIRECTION** - Natural movement of air of any velocity. Speed: The velocity of the wind measured in knots or miles per hour. Direction: One or more of sixteen points of the compass with relation to the point of observation of the wind.

**WINDBREAK** - A barrier erected or planted to absorb and/or deflect some of the wind force and thus lower the wind velocity on the leeward side of the barrier. Used to protect crops, soil, personnel, or other parts of the environment from the effects of wind.



**WIND EROSION EQUATION** - An equation for predicting  $E$ , the average annual soil loss due to wind in mass per unit per year, and is defined as  $E = KCLV$ , where  $I$  is the soil erodibility factor,  $K$  is the soil ridge roughness factor,  $C$  is the local climatic factor,  $L$  is the field width, and  $V$  is the vegetative factor.

**WORK PARTY, Superfund** - A minimum of two individuals who perform onsite task necessary to fulfill the objectives of the investigation, e.g., obtaining samples of soils, air or water, or determining the location of monitoring wells.

**XENOBIOTIC** - A compound foreign to biological systems. Often refers to human-made compounds that are resistant or recalcitrant to biodegradation and/or decomposition. See recalcitrant molecules.

**XERIC SOILS** - Soils with a limited amount of water present, and water not occurring at optimum periods for plant growth. Also see soil moisture (water) content.

**YEASTS** - Minute fungi, especially *Saccharomyces cerevisia*, usually having little or no mycelia (thread-like structures) and reproducing by budding. Any of the various similar fungi, especially orders Endomycetales and Moniliales.

**ZEOLITES** - Any of the hydrous silicates, natural or synthetic. Used in water softening and as adsorbents and catalysts. Important in the immobilization of specific elements.

**ZYMOGENOUS MICROBIOTA** - Microorganisms found in soils in larger numbers immediately after the addition of easily decomposable organic material, including certain contaminant organics.

## APPENDIX C

## EXAMPLE OF SOIL DESCRIPTION FORM MODIFICATION FROM SOIL CONSERVATION

**SERVICES FORM SCS-S01-232 (3-87) FOR US EPA ENVIRONMENTAL**

## MONITORING AND ASSESSMENT PROGRAM

[illegible]

SOIL SERIES												DATE			SITE ID		MLRA
												MM	DD	YY	ST	HEX	

[illegible][illegible][illegible]

## Site Comments

**Film :   ROLL #   EXP #**

## Soil Profile

## Tree Canopy

### Understory Veg

## Landscape

H O R Z	DEPTH		HORIZON DESIGNATION		MOIST COLOR				BOUN- DARY D T	TEXTURE	
	UPPER LOWER	D S C	MASTER LETTER	SUFFIX	L O C	HUE	V A L	C H R		CLASS	MOD
1											
2											
3											
4											
5											
6											

H O R Z	HOLE 1	HOLE 2	HOLE 3	HOLE 4	HOLE 5	HOLE 6	HOLE 7	HOLE 8	HOLE 9	HOLE 10	HOLE 11	HOLE 12
	DEPTH	DEPTH	DEPTH	DEPTH	DEPTH	DEPTH	DEPTH	DEPTH	DEPTH	DEPTH	DEPTH	DEPTH
	UPPER LOWER	UPPER LOWER	UPPER LOWER	UPPER LOWER	UPPER LOWER	UPPER LOWER	UPPER LOWER	UPPER LOWER	UPPER LOWER	UPPER LOWER	UPPER LOWER	UPPER LOWER
O												
A												
E												
B												
C												

H O R Z	STRUCTURE			MOTTLES				FIELD PROPERTIES		H C	ROOTS			
	G R D	SZ	SHP	A B	SZ	C O N	HUE	V A L	C H R		KND	AMOUNT	QT	SZ
1														
2														
3														
4														
5														
6														

### Horizon Comments

Horizon

1 \_\_\_\_\_

2 \_\_\_\_\_

3 \_\_\_\_\_

4 \_\_\_\_\_

5 \_\_\_\_\_

6 \_\_\_\_\_

General:

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

H O R Z	PORES				CONCENTRATIONS				ROCK FRAGMENTS			
	SHP	QT	SZ	C N	KND	QT	S H P	SZ	K N D	R N D	S N D	Z
1												
2												
3												
4												
5												
6												

SAMPLE COLLECTION SUMMARY					
PLOT: STATE _____ HEX _____ SET ID _____					
HOR	SAMPLED (Y/N)	INDIV #	COMPOSITE #	BULK DENSITY (Y/N)	OM BIOMASS (Y/N)
O					
A					
E					
B					
C					
TOTAL	NA			NA	

**BASE PAGE CODES****Slope Shape (U/A)**

- 1 convex
- 2 plane
- 3 concave
- 4 undulating
- 5 complex

**Geomorphic Component (GM)**

- 1 interfluvial
- 2 head slope
- 3 side slope
- 4 nose slope

**Hillslope Component (HS)**

- 1 summit
- 2 shoulder
- 3 back slope
- 4 foot slope
- 5 toe slope

**Slope Aspect (ASP)**

- 45 northeast
- 90 east
- 135 southeast
- 180 south
- 225 southwest
- 270 west
- 315 northwest
- 0 north

**Major Landform (MAJ)**

- BA Badlands
- BI Barrier Island
- BO Bolson
- CA Canyon
- CF Coalescent Fan Piedmont
- CP Coastal Plain
- DF Drumlin Field
- DP Deeply Dissected Plateau
- FH Foothills
- GF Glaciofluvial Landform
- GU Glaciated Upland
- HH High Hills
- HI Hills
- KP Karst Plain
- LP Lake Plain
- LU Level or Undulating Upland
- LV Lava Plain
- MO Mountains
- MV Mountain Valley
- PI Piedmonts
- PL Plains
- PT Plateau
- RV River Valley
- SB Semibolson
- SH Sandhills
- TA Tableland
- VM Volcanic Mountains

**Local Landform (LOC)**

- AF Alluvial Fan
- AP Alluvial Flat (plain)
- BE Beach
- BF Barrier Flat
- BO Bog
- BS Backswamp
- BT Beach Terrace
- BU Butte
- CB Carolina Bay
- CO Cove
- CR Crater
- CU Cuesta
- DE Delta
- DO Dome
- DR Drumlin
- DU Dune
- EK Esker
- EM End Moraine
- ES Escarpment
- FE Felsenmeer
- FP Flood Plain
- FT Fluvial Terrace
- FJ Fjord
- GM Ground Moraine
- HO Hogback
- HS Hillside
- KA Kame
- KE Kettle
- LS Low Sand Ridge
- LT Lake Terrace
- MA Marsh
- ME Mesa
- MO Mountainside
- MT Marine Terrace
- OP Outwash Plain
- OT Outwash Terrace
- OX Oxbow
- PE Pediment
- PL Playa
- RI Ridge
- SB Structural Bench
- SI Sink
- SL Slough
- SM Salt Marsh
- SW Swamp
- VC Volcanic Cone
- VS Valleyside

**Moisture Regime (MST RGE)**

- AQ aquic
- AR aridic
- PA peraquic
- PU perudic
- TO torric
- UD udic
- US ustic
- XE xeric

**Kind of Watertable (KD)**

- 0 none
- 2 perched
- 3 apparent
- 4 ground

**Land Use (LU)**

- A abandoned cropland
- C cropland
- E forest land grazed
- F forest land not grazed
- G pasture land and native pasture
- H horticultural land
- I cropland irrigated
- J hayland
- L waste disposal land
- N barren land
- O other
- P rangeland grazed
- Q wetlands drained
- R wetlands
- S rangeland not grazed
- T tundra
- U urban and built-up land

**Stoniness Class (ST)**

- 0 class 0
- 1 class 1
- 2 class 2
- 3 class 3
- 4 class 4
- 5 class 5

**Hydraulic Conductivity Class (HC)**

- 1 very slow
- 2 slow
- 3 moderately slow
- 4 moderate
- 5 moderately rapid
- 6 rapid
- 7 very rapid

**Drainage Class (DR)**

- 1 very poorly drained
- 2 poorly drained
- 3 somewhat poorly drained
- 4 moderately well drained
- 5 well drained
- 6 somewhat excessively drained
- 7 excessively drained

**Parent Material****Bedrock Inclination (B)**

- 1 < 5 degree inclination
- 2 5-30 degree inclination
- 3 > 30 degree inclination

**Parent Material Mode of Deposition (M)**

A	alluvium
D	glacial drift
E	eolian
F	mine spoil and earth fill
G	glacial outwash
H	volcanic ash
I	lacustrine sands
J	lacustrine silts
K	lacustrine clays
L	lacustrine
M	marine
N	marine sands
O	organic
P	marine silts
Q	marine clays
R	solid rock
S	eolian-sand
T	glacial till
U	unconsolidated sediments
V	local colluvium
W	loess
X	residuum
Y	solifluctate
Z	estuarine

**Parent Material Origin (ORIG)**

A0	sandstone unspecified
A1	sandstone-noncalcareous
A2	arkosic-sandstone
A4	sandstone-calcareous
B0	interbedded sedimentary unspecified
B1	limestone-sandstone-shale
B2	limestone-sandstone
B3	limestone-shale
B4	limestone-siltstone
B5	sandstone-shale
B6	sandstone-siltstone
B7	shale-siltstone
C0	conglomerate unspecified
C1	conglomerate-noncalcareous
C2	conglomerate-calcareous
E0	ejecta-ash unspecified
E1	acidic-ash
E2	basic-ash
E3	basaltic-ash
E4	andesitic-ash
E5	cinders
E6	pumice
E7	scoria
E8	volcanic bombs
H0	shale unspecified
H1	shale-noncalcareous
H2	shale-calcareous
H3	shale-clay
I0	igneous unspecified
I1	igneous-coarse (or intrusive)
I2	igneous-basic (eg., gabbro)
I3	igneous-intermediate (eg., diorite)
I4	igneous-granite
I5	igneous-fine (or extrusive)
I6	igneous-basalt
I7	igneous-andesite

I8	igneous-acid (eg., rhyolite)
I9	igneous-ultrabasic
K0	organic unspecified
K1	mossy material
K2	herbaceous material
K3	woody material unspecified
K4	wood fragments

**Parent Material Origin (cont.)**

K5	logs and stumps
K6	charcoal
K7	coal
L0	limestone unspecified
L1	chalk
L2	marble
L3	dolomite
L4	limestone-phosphatic
L5	limestone-arenaceous
L6	limestone-argillaceous
L7	limestone-cherty
M0	metamorphic unspecified
M1	gneiss unspecified
M2	gneiss-acidic
M3	gneiss-basic
M4	serpentine
M5	schist unspecified
M6	schist-acidic
M7	schist-basic
M8	slate
M9	quartzite
P0	pyroclastic unspecified
P1	tuff unspecified
P2	tuff-acidic
P3	tuff-basic
P4	volcanic breccia unspecified
P5	breccia-acidic
P6	breccia-basic
P7	tuff-breccia
P8	aa
P9	pahoehoe
S0	sedimentary unspecified
S1	marl
S2	glauconite
T0	siltstone unspecified
T1	siltstone-noncalcareous
T2	siltstone-calcareous
Y0	mixed unspecified
Y1	mixed-noncalcareous
Y2	mixed-calcareous
Y4	mixed-igneous-metamorphic & sed.
Y5	mixed-igneous & metamorphic
Y6	mixed-igneous & sedimentary
Y7	mixed-metamorphic & sedimentary
MS	meta-sedimentary

**Bedrock fracture (BR)**

1	< 10 cm between fractures
2	10 to 45 cm between fractures
3	45 cm to 1.0 m between fractures
4	1.0 to 2.0 m between fractures
5	> 2.0 m between fractures

**Hydrologic group (HG)**

A	> 6 inches/hour
---	-----------------

B	0.6 - 6 inches/hour
C	0.06 - 0.6 inches/hour
D	< 0.06 inches/hour

**Erosion Class (ER)**

0	none
1	slight
2	moderate
3	severe

**Runoff Class (RO)**

1	none
2	ponded
3	very slow
4	slow
5	rapid
6	moderate
7	very rapid

**Flooding and Ponding, frequency (FF/PF)**

NO	none
RA	rare
OC	occasional
FR	frequent
CO	common

**Diagnostic Features (KND)**

A	anthropic
B	cambic
C	calcic
D	durinodes
E	petrocalcic
F	fragipan
G	gypsic
H	histic
I	sombric
J	petrogypsic
K	placic
L	lithic contact
M	mollic
N	natric
O	ochric
P	plaggen
Q	albic
R	argic
S	spodic
T	argillic
U	umbric
V	sulfuric
W	paralithic contact
X	oxic
Y	salic
Z	duripan
1	kandic

# HORIZON CODES

## Color location (LOC)

0	not given
1	interior
2	exterior
3	crushed
4	dithionite-citrate pretreated
5	after exposure to air
6	after ignition
7	pyrophosphate extract

## Boundary distinctness

A	abrupt
C	clear
D	diffuse
G	gradual

## Boundary topography

B	broken
I	irregular
S	smooth
W	wavy

## Texture class (CLASS)

C	clay
CE	coprogenous earth
CIND	cinders
CL	clay loam
COS	coarse sand
COSL	coarse sandy loam
CSCL	coarse sandy clay loam
DE	diatomaceous earth
FB	fibric material
FM	fragmental material
FS	fine sand
FSL	fine sandy loam
G	gravel
GYP	gypsiferous earth
ICE	ice or frozen soil
L	loam
LCOS	loamy coarse sand
LFS	loamy fine sand
LS	loamy sand
LVFS	loamy very fine sand
MARL	marl
MPT	mucky peat
MUCK	muck
OPWD	oxide protected weathered bedrock
PDOM	partially decomposed organics
PEAT	peat
S	sand
SC	sandy clay
SCL	sandy clay loam
SG	sand and gravel
SI	silt
SIC	silty clay
SICL	silty clay loam
SIL	silt loam
SL	sandy loam
SP	sapric material
U	unknown texture
UDOM	undecomposed organics
UWB	unweathered bedrock

VAR	variable
VFS	very fine sand
VFSL	very fine sandy loam
WB	weathered bedrock

## Texture modifier (MOD)

BY	bouldery
BYV	very bouldery
BYX	extremely bouldery
CB	cobbly
CBA	angular cobbly
CBV	very cobbly
CBX	extremely cobbly
CN	channery
CNV	very channery
CNX	extremely channery
FL	flaggy
FLV	very flaggy
FLX	extremely flaggy
GR	gravelly
GRC	coarse gravelly
GRF	fine gravelly
GRV	very gravelly
GRX	extremely gravelly
ST	stony
STV	very stony
STX	extremely stony

## Structure grade (GRD)

0	structureless
1	weak
2	moderate
3	strong
4	very strong
5	weak and moderate
6	moderate and strong

## Structure size (SZ)

CO	coarse
CV	coarse and very coarse
F	fine
FF	very fine and fine
FM	fine and medium
M	medium
MC	medium and coarse
TK	thick
TN	thin
VC	very coarse
VF	very fine
VK	very thick
VN	very thin

## Structure shape (SHP)

ABK	angular blocky
BK	blocky
CDY	cloddy
COL	columnar
CR	crumb
GR	granular
LP	lenticular
MA	massive
PL	platy
PR	prismatic
SBK	subangular blocky
SGR	single grain
WEG	wedge

## Mottle abundance (AB)

F	few
C	common
M	many

## Mottle size (SZ)

1	fine
12	fine and medium
13	medium and coarse
2	medium
3	coarse

## Mottle distinctness

D	distinct
F	faint
P	prominent

## Kind of field measurement (KND)

CL	clay
PB	Bromthymol blue
PC	Cresol red
PG	Bromcresol green
PH	hellige-truog
PL	LaMotte-Morgan
PP	Phenol red
PR	Chlorophenol red
PS	soiltest
PT	Thymol-blue
PY	pH Ydrion
SA	sand
SC	coarse and very coarse sand
SF	fine sand
SI	silt
SM	medium sand
SV	very fine sand
OB	fiber unrubbed
OR	rubbed fiber

## Hydraulic conductivity class

1	Very slow
2	slow
3	Moderately slow
4	Moderate
5	Moderately rapid
6	Rapid
7	Very rapid

## Root quantity (QT)

VF	very few
FF	very few to few
F	few
FC	few to common
C	common
CM	common to many
M	many

## Root size (SZ)

1	fine 1-2mm
11	very fine and fine
12	fine and medium
13	fine to coarse
2	medium 2-5mm
23	medium and coarse
3	coarse > 5mm
V1	very fine < 1mm



Root location (LOC)  
 C in cracks  
 M in mat at top of horizon  
 P between peds  
 S matted around stones  
 T throughout

Shape of pore (SHP)  
 IE filled with coarse material  
 IF void between rock fragments  
 IR interstitial  
 IT interstitial and tubular  
 TC continuous tubular  
 TD discontinuous tubular  
 TE dendritic tubular  
 TS constricted tubular  
 TU tubular  
 VS vesicular  
 VT vesicular and tubular

Quantity of pores (QT)  
 VF very few  
 FF very few to few  
 F few  
 FC few to common  
 C common  
 CM common to many  
 M many

Size of pore (SZ)  
 1 fine .05-2mm  
 11 very fine and fine  
 12 fine and medium  
 13 fine to coarse  
 2 medium 2-5mm  
 23 medium and coarse  
 3 coarse > 5mm  
 V1 very fine < .05mm

Pore Continuity (CN)  
 L Low  
 M Moderate  
 H High

Kind of concentration (KND)  
 A2 clay bodies  
 B1 barite crystals  
 B2 soft masses of barite  
 C1 calcite crystals  
 C2 soft masses of lime  
 C3 lime concretions  
 C4 lime nodules  
 D1 mica flakes  
 D2 soft dark masses  
 D3 dark concretions  
 D4 dark nodules  
 E3 gibbsite concretions  
 E4 gibbsite nodules  
 F1 plinthite segregations  
 F2 soft masses of iron  
 F3 iron concretions  
 F4 ironstone nodules  
 G1 gypsum crystals  
 G2 masses of gypsum  
 G3 nests of gypsum  
 G4 gypsum threads

H1 halite crystals  
 H2 salt masses  
 K2 soft masses of carbonate  
 K3 carbonate concretions  
 K4 carbonate nodules  
 K5 carbonate threads  
 M1 nonmagnetic shot  
 M2 soft masses of iron-manganese  
 M3 iron-manganese concretions  
 M4 magnetic shot  
 S1 opal crystals  
 S2 soft masses of silica  
 S3 silica concretions  
 S4 durinodes  
 T2 worm casts  
 T3 insect casts  
 T4 worm nodules

Quantity of concentrations (QT)  
 VF very few  
 FF very few to few  
 F few  
 FC few to common  
 C common  
 CM common to many  
 M many

Shape of concentration (SHP)  
 C cylindrical  
 D dendritic  
 O rounded  
 P plate like  
 T threads  
 Z irregular

Size of concentration (SZ)  
 1 fine <2mm  
 12 fine and medium  
 2 medium 2-5mm  
 23 medium and coarse  
 3 coarse > 5-20mm  
 34 coarse and very coarse  
 4 very coarse 20-76mm  
 45 very coarse and extremely coarse  
 5 extremely coarse > 76mm

Kind of rock fragment (KND)  
 A sandstone  
 B mixed sedimentary  
 E ejecta  
 F ironstone  
 H shale  
 I igneous rocks  
 K organic fragments  
 L limestone  
 M metamorphic rocks  
 O oxide-protected rock  
 P pyroclastic rocks  
 R saprolite  
 S sedimentary rocks  
 Y mixed lithology

Roundness of rock fragment (RND)

1 angular  
 2 subangular  
 3 subrounded  
 4 rounded  
 5 well rounded

Size of rock fragment (SZ)

1 pebbles  
 2 cobbles  
 3 stones  
 4 boulders  
 5 channers  
 6 flagstones

## APPENDIX D

### METHODS FOR DETERMINATION OF SITE AND SOIL PARAMETERS

Adapted from Russell Boulding (Eastern Research Group)

SOIL PARAMETER	FIELD DETERMINATION	LABORATORY METHOD	CALCULATION/LOOKUP
1. WATER BUDGET			
Precipitation	Sacramento gage (accumulated precipitation, manual recording), weighing gage (continuous measurement, mechanical recording), or tipping-bucket gage (continuous measurement with electronic recording)--Finkelstein et al. (1983).		Precipitation data collected by National Weather Service or other source for area near site. Interpolation using published maps of precipitation data.
Infiltration	Cylinder infiltrometer (Bouwer, 1986) and sprinkler infiltrometer (Peterson and Bubenzer (1986).		Methods available for estimating infiltration of small watersheds (Dunne and Leopold, 1978), large watersheds (Musgrave and Holtan (1964)). Infiltration equations can be used using field-measured or literature estimates (Green and Ampt, 1911; Philip 1957).
Evaporation	Class-A Pan evaporation from surface of free liquid (Veihmeyer, 1964; NWS 1972) direct measurement of bare soil evaporation using a weighing lysimeter (USGS, 1977).		Interpolation using maps showing average evaporation.
Evapo-transpiration	Direct field methods include use of lysimeters (Boast, 1986; Sharma, 1985; Veihmeyer, 1964), soil moisture sampling (Veihmeyer, 1964), and potential evapotranspirimeters (Thornthwaite and Mather, 1957). Indirect field methods include chloride tracer (Sharma, 1985) and ground-water fluctuation (Davis and Dewiest, 1966).	Chloride tracer method requires laboratory analyses (Sharma, 1985). Indirect micrometeorologic methods include the profile method (Sharma, 1985) and energy budget/Bowen ratio, eddy covariance methods, and Penman equation (Veihmeyer, 1964; Sharma 1985).	Three commonly used empirical equations are the Thornthwaite equation (Veihmeyer, 1964; Sharma 1985), and the Blaney-Criddle equation (Stephens and Stewart, 1964); and the Jensen-Haise equation (Jensen and Haise, 1963).
Surface Runoff	Field observations using SCS soil runoff classes allows qualitative estimation (see Section 12.e in Boulding, 1991).		Can be calculated from precipitation, soil moisture and infiltration data. SCS soil series interpretation sheets provide hydrologic soil group for surface runoff calculations using the SCS curve runoff method (USDA SCS, 1975).

# METHODS FOR DETERMINATION OF SITE AND SOIL PARAMETERS, Continued

SOIL PARAMETER	FIELD DETERMINATION	LABORATORY METHOD	CALCULATION/LOOKUP
2. OTHER CLIMATE /WEATHER PARAMETERS			
Air Temperature	Thermometry (Taylor and Jackson, 1986), see also Section 2.12f in Boulding, 1991).		Brown et al. (1983) provide maps with temperature data. See also, National Climatic Data Center (1983) for possible sources. Schroeder et al. (1983) include insolation data for 102 cities.
Wind Speed	Cup or propeller anemometer (Finkelstein et al. 1983; Kite, 1979).		
Humidity	Use sling psychrometer for obtaining wet-bulb and dry-bulb air temperatures for calculation of relative humidity and dew point.		See National Climatic Data Center (1983) for possible sources.
Insolation	Thermopile pyranometer or silicon photovoltaic cell (Thompson, et al., 1989)		See National Climatic Data Center (1983) for possible sources. Schroeder et al. (1983) include insolation data for 102 cities.

# METHODS FOR DETERMINATION OF SITE AND SOIL PARAMETERS, Continued

SOIL PARAMETER	FIELD DETERMINATION	LABORATORY METHOD	CALCULATION/LOOKUP
3. GEOMORPHOLOGY			
Slope (%)	Measure slope gradient and length for erosion modeling.		Can be measured from site topographic surveys.
Slope form/landscape position	Observation of slope form and shape may help in location of areas where contaminants have been concentrated by surface erosion.		The surface hydrology of hill slope systems is generalized by the SCS curve number and hydrologic soil groups (see 1.e above).
Erodibility	Field measurement of slope, field length, cover type.		Estimated using standard equations and graphs (Isrealson et al., 1980). Soil data can be obtained from local SCS office.
Water Erosion (USLE or RUSLE)	Measurement/survey of slope (in. ft. rise/ft. run or %), length of field and vegetation cover.		The universal soil loss equation (USLE) (Wischmeier and Smith, 1978); revised version (Renard et al. 1991) and the new generation WEPP (Laflen et al. (1991). See Mills et al. (1985) and U.S. EPA (1988d) for use guidance.
Wind Erosion	Measure field length along prevailing wind direction.		SCS wind erosion equation (WEQ) (Woodruff and Siddoway, 1965; Israelson et al. 1980). Cowherd et al. (1985) describe method for rapid evaluation of particles from a Superfund site.

METHODS FOR DETERMINATION OF SITE AND SOIL PARAMETERS, Continued

SOIL PARAMETER	FIELD DETERMINATION	LABORATORY METHOD	CALCULATION/LOOKUP
5. SURFACE HYDROLOGY			
Surface Streams	Field observation of drainage way location, and whether they are ephemeral, intermittent or perennial.		Areal photographs, topographic and other types of maps.
Flood Plains/Frequency/Duration	Engineering and hydrologic field measurements to estimate extent and frequency of flooding.		Check for availability of flood hazard boundary maps prepared for the Federal Emergency Management Agency and the Federal Insurance Administration.
Water Bodies	Map location and measure size, and variations in water levels over time.		Areal photographs, topographic and other types of maps.
6. SITE BIOTA			
Vegetative Cover	Map current vegetation types. Vogel (1987) describes procedures for mapping and sampling vegetation. USDA can aid in identification of unknown plant species.		Air photographs taken at different years can be used to evaluate changes in vegetation over time. Available from ASCS, SCS.

# METHODS FOR DETERMINATION OF SITE AND SOIL PARAMETERS, Continued

SOIL PARAMETER	FIELD DETERMINATION	LABORATORY METHOD	CALCULATION/LOOKUP
Horizons	Soil pits dug with backhoe are best. If safety and cost are a concern, soil cores can be collected with a tube-type sampler.	Laboratory texture analyses and chemical tests may be required to confirm or refine horizon breaks defined in the field.	SCS soil survey, if available will provide guidance in types of soil horizons that are likely to be encountered.
Texture	Field determination by feel to estimate percent silt, sand and clay. Collect composite sample of each soil horizon for laboratory determination.	ASTM D 522-63 Method for Particle Analysis of Soils. Sieve analysis better at hazardous waste site because organics can affect hydrometer analysis (U.S. EPA, 1987a).	SCS soil survey, if available will indicate ranges of texture that can be expected in different horizons for specific soil series.
Color	Soil colors can be precisely described according to hue, value, and chroma using Munsell Soil color charts.	It may be useful to record color or air-drying samples.	SCS soil series description sheets indicate typical ranges of colors of different soil horizons.
Porosity (pore volume)	SCS method for description of pore size and distribution can provide insight into paths for contaminant transport.	Gas pycnometer (Danielson and Sutherland, 1986).	Calculated from particle and bulk densities (Danielson and Sutherland, 1986).
11. ZONES OF INCREASED SECONDARY POROSITY/PERMEABILITY			
Structure	Use SCS classification system and description procedures (Boulding 1991).		
Roots	Use SCS classification system and description procedures (Boulding, 1991).		
Lateral Features	Use SCS classification system and description procedures (Boulding, 1991).	Clay mineral identification may be desirable when stress formations are observed (see clay mineralogy)	
Sedimentary Features	Describe type, thickness, and orientation (Boulding, 1991).		

# METHODS FOR DETERMINATION OF SITE AND SOIL PARAMETERS, Continued

SOIL PARAMETER	FIELD DETERMINATION	LABORATORY METHOD	CALCULATION/VALUE
12. ZONES OF REDUCED POROSITY/PERMEABILITY			
Genetic Horizons	Use SCS criteria and description procedures. See Table 2-4 in Boulding (1991) for cementation test.	See discussion of rupture resistance below.	SCS soil survey will identify soil series with horizons of reduced permeability.
Rupture Resistance (consistency)	Use SCS field tests and description procedures. See Table 2-4 in Boulding (1991).	Laboratory testing can provide more precise classification of samples. Cementation test procedure can be more easily done in the laboratory.	
Bulk Density	Neutron probe (ASTM, 1981); gamma radiation (Blake and Hartge, 1986).	Coring or excavation for lab analysis (Blake and Hartge, 1986).	SCS soil series interpretation records contain estimated ranges of bulk density.
Root Restriction Depth	Use SCS criteria and description procedures (Boulding, 1991).		
13. SOIL ENGINEERING PROPERTIES/PARAMETERS			
Compaction	Not amenable to field estimation.	Proctor density test or moisture density test (ASTM D-698) used to determine moisture content at which maximum density occurs with compaction.	
Corrosivity	Can be inferred from field estimated or measured properties. SW 846 (US EPA, 1986b) requires a sample of liquid waste for pH (<2 or > 12.5) and corrosivity toward steel.	SW 846 (US EPA, 1986b) uses method 1110 to measure the corrosivity toward steel of both aqueous and nonaqueous liquid wastes.	SCS soil series interpretation sheets give corrosivity ratings for steel and concrete. USDA SCS (1983) provides quantitative criteria for rating soil corrosion potential for uncoated steel and cement based on parameters mentioned in column 1.

# METHODS FOR DETERMINATION OF SITE AND SOIL PARAMETERS, Continued

SOIL PARAMETER	FIELD DETERMINATION	LABORATORY METHOD	CALCULATION/LOOKUP
14. SOIL WATER STATE			
Moisture Content	Carbide gravimetric methods can be used in field (Wilson, 1981). Most common indirect field method is neutron scattering (van Bavel, 1963, Gardner, 1986). Other indirect methods include electrical conductivity and capacitance, and gamma ray or neutron attenuation (Gardner, 1986).	Gravimetric analysis of field-collected samples is the most accurate method (Gardner, 1986).	Can be inferred by measuring water potential in the field or laboratory (see 9.b below) and using moisture retention curves (see 9.c below).
Water Potential	Water potential in saturated soils is measured using piezometry (Reeve, 1986). The most common field method for measuring negative potential is tensiometry (Cassel and Klute, 1986). Field psychrometers can also be used (Rawlins and Campbell, 1986).	Laboratory measurements of field collected samples at different water contents using tensiometry (Cassel and Klute (1986) or thermocouple psychrometry (Rawlins and Campbell) are usually used to measure specific retention (see 9.c below). Electrical resistance and heat dissipation sensors can also be used (Campbell and Gee (1986).	Can be inferred from moisture retention curve (9.c below) by measuring water content of soil (9.a above).
Available Water Capacity (AWC)	Collection of soil samples just after the soil has drained following a period of rain and humid weather, after a spring thaw, or after heavy irrigation (see Section I.4.1 in USDA SCS, 1971; 1983).	Measurement of soil moisture at field capacity and 15-bar moisture content, and bulk density (USDA SCS, 1983).	SCS soil series interpretation sheets provide ranges of available water capacity for individual soil horizons.
Soil Moisture Regime	Not measured in field		Usually determined by using climatic and soil data to develop a monthly soil water balance. SCS taxonomic classification will indicate the moisture regime of a soil series.



# METHODS FOR DETERMINATION OF SITE AND SOIL PARAMETERS, Continued

SOIL PARAMETER	FIELD DETERMINATION	LABORATORY METHOD	CALCULATION/LOOKUP
15. INTERNAL FREE WATER (saturated zone)	Ground-water monitoring wells or piezometers using EPA approved methods (Aller et al., 1989; Reeve 1986). Depth, thickness and duration (if perched) should be measured.		SCS soil series data sheet provide estimates of depth, thickness, and duration of shallow/perched water tables.
16. PERMEABILITY/HYDRAULIC CONDUCTIVITY			
Saturated Hydraulic Conductivity (Ksat)	Auger-hole and piezometer methods (Amoozegar and Warrick, 1986) and Guelph permeameter (Reynolds and Elrick, 1985 and 1986). SW 846 (US EPA, 1986b) provides methods requiring a single bore hole or piezometers; areal methods are included for reference purposes.	Constant head and falling head methods (Amoozegar and Warrick, 1986; Klute and Dirksen, 1986). SW 846 (US EPA, 1986b) details methods for constant and falling head conditions using specific types of laboratory apparatus and their applicability to remolded compacted, and fine-grained uncompact, and coarse-grained porous media.	Freeze and Cherry (1979) provide ranges for different geologic materials, and USDA SCS (1990) provides range for Unified soil texture classes. SW 846 (US EPA, 1986b) provides calculations, theory, and measurements for tests, including the modified slug test. Laboratory and field methods are described to determine fluid conductivity of materials used for liners, caps, and drains at waste-disposal facilities as well as materials composing the local ground water flow systems.
Unsaturated Hydraulic Conductivity (Kunsat.)	Constant-head borehole infiltration (Amoozegar and Warrick, 1986); instantaneous profile, crust- and sprinkler-imposed steady flux methods (Green et al. 1986); air entry permeameter (Bouwer, 1966).	Klute and Dirksen (1986) describe 8 methods, the main ones being steady-state head and steady-state flux control.	Parameter identification uses results of one field or lab test to develop conductivity over a range of moisture contents (Zachmann et al. 1982; Kool et al., 1985). Empirical equations (Mualem, 1986; van Genuchten, 1980, in press). SW 846 (US EPA, 1986b) does not include methods for hydraulic conductivity at this time because Part 264 permitting standards do not require such determinations.

METHODS FOR DETERMINATION OF SITE AND SOIL PARAMETERS, Continued

SOIL PARAMETER	FIELD DETERMINATION	LABORATORY METHOD	CALCULATION/LOOKUP
17. CONTAMINANT TRANSPORT IN SOIL WATER			
Dispersivity	Any method used to identify zones of increased permeability (see Section 5, Table 1). Tracer tests can be used in the saturated and unsaturated zone, borehole flowmeters in the saturated zone.	Use of column and flow-through tests (Van Genuchten and Wierenga, 1986).	Where no data are available factors for hydrodynamic dispersion may be estimated for use in transport modeling.
18. VOLATILIZATION			
Air Temperature	See climate/weather	Same as field.	See climate/weather
Wind Speed	See climate/weather		See climate/weather
19. GROUND TEMPERATURE			
Soil Temperature	Thermometry (Taylor and Jackson, 1986), see also Section 2.12f in Boulding, 1991 for estimation of average annual temperature.	Same as field.	Brown et al. (1983) provide maps with temperature data.
Soil Temperature Regime	Usually not measured in the field.		Usually estimated from climatic data. Soil temperature regime is part of the SCS taxonomic classification of a soil series.

SOIL PARAMETER	FIELD DETERMINATION	LABORATORY METHOD	CALCULATION/LOOKUP
20. SOIL CHEMISTRY			
Organic Carbon/Matter	Color provides a rough indication of organic matter content of soils. See also Test 11 in Section 2.8a in Boulding (1991).	Different methods are used to measure total, inorganic and organic carbon. Most involve high temperature combustion (wet or dry) and oxidation techniques (Nelson and Sommers, 1982). Due to difficulty in identifying natural versus added organic carbon, correct analysis at contaminated sites is a problem (Powell et al., 1989; Powell, 1990). Characterization of stable humic substances in OM may be desirable (Schnitzer, 1982).	
Odor	Used in ASTM (unified) soil classification system to identify organic soils (see Test 11 in section 2.8a in Boulding, 1991).		
Cation Exchange Capacity (CEC)	Representative samples of major horizons and strata required for laboratory analysis. Collect samples in accordance with SW 846 (US EPA, 1986b).	Chapman (1965) describes standard methods for measurement of CEC; Rhoades (1982a) describes special procedures for arid and highly weathered tropical soils. Thomas (1982) describes methods for determination of total exchangeable cations. SW 846 (US EPA, 1986b) methods 9080 and 9081 refer to Chapman (1965).	Rough estimates possible from particle size distribution and clay mineralogy. SW 846 (US EPA, 1986b) uses a sampling plan that addresses collection, preservation and handling.
Soil pH	Measured in field same manner as in laboratory.	Using a glass electrode in an aqueous slurry (McLean, 1982). SW 846 (US EPA, 1986b) method 9045 is an electrometric method for measuring pH in calcareous and noncalcareous soils; method also provided for sample preparation.	SCS soil series description will include pH class descriptors for each soil horizon. SW 846 (US EPA, 1986b) cautions against errors that may occur when electrodes become coated.

METHODS FOR DETERMINATION OF SITE AND SOIL PARAMETERS, Continued

SOIL PARAMETER	FIELD DETERMINATION	LABORATORY METHOD	CALCULATION/LOOKUP
Soil Oxygen	Platinum or membrane electrode methods (Phene, 1986) or use of field gas chromatograph (Smith and Arab, 1991).	Same as field. In saturated soils, dissolved oxygen is analyzed using EPA 360.1 or 360.2-electrometric membrane electrode and titrimetric, modified Winkler methods (Kopp and McKee, 1983).	Calculated from pE (Stumm and Morgan, 1981) or from aerial oxygen and soil gas diffusion rate.
Redox Potential (Eh)	Platinum electrode used on lysimeter sample (ASTM, 1976).	Same as field.	Can be calculated from concentration of redox pairs of oxygen (Stumm and Morgan, 1981).
Redox Couple Ratios (waste soil system)	Lysimeter or ground-water samples for laboratory analysis.	Analysis of concentrations of redox pairs. Thompson et al. (1989) summarize methods for measurement of redox sensitive species.	
Clay Mineralogy	See Section 2.15g in Boulding (1991).	Thompson et al. (1989) review 8 methods for analyzing clay mineralogy. The most common methods are X-ray diffraction (Whittig and Allerdice, 1986), and scanning electron microscopy (Goldstein et al. 1981), sometimes supplemented with chemical analyses (Jackson et al. 1986).	SCS soil series taxonomic classification provides a general idea of clay mineralogy.

# METHODS FOR DETERMINATION OF SITE AND SOIL PARAMETERS, Continued

SOIL PARAMETER	FIELD DETERMINATION	LABORATORY METHOD	CALCULATION/LOOKUP
Other Mineralogy	Hydrochloric acid test for calcium carbonate; other mineral concentrations can be identified visually (see Section 2.15h in Boulding, 1991).	The most common method for identification of non-clay minerals is optical microscopy (Cady et al. 1986). Nelson (1982) describe methods for analysis of carbonate and gypsum. See also methods for clay mineralogy above.	Soils where specific non-clay minerals form a significant percentage of the soil texture are identified in a soil series taxonomic mineralogy class.
Salinity	Measurement of electrical conductivity of a saturation extract from soil, or ground-water sample (Rhoades, 1982b). See also other methods for measurement of water flux that sense dissolved solids (see 13.a)	Same as field.	SCS soil series descriptions may specify soil salinity classes where soluble minerals are significant in the soil profile.
Sodicity/SAR (sodium adsorption ratio)	The surface of sodic soils is usually discolored by the dispersed humus carried upward by capillary water.	Analysis of concentrations of sodium, calcium and magnesium in a saturation extract. See ***.	SAR is calculated from data on the amount of sodium, calcium, and magnesium in the soil (USDA SCS, 1991).
Major Cations	Collection of samples of soil solids or ground water for laboratory analysis required.	Knudsen et al. (1982) describe methods for analyzing for sodium and potassium, and Lanyon and Heald, (1982) for calcium and magnesium in soil extracts.	
Major Anions	Collection of samples of soil solids or ground water for laboratory analysis required.	Thompson et al. (1989) review 18 recommended methods for analysis of anionic species in aqueous solution, and 21 methods for anionic species and ammonium ion in solids.	
Fertility Potential	Sampling of soil for laboratory analysis of nutrients of interest.		

# METHODS FOR DETERMINATION OF SITE AND SOIL PARAMETERS, Continued

SOIL PARAMETER	FIELD DETERMINATION	LABORATORY METHOD	CALCULATION/LOOKUP
21. SOIL BIOTA	No standard method exists. See model of remedial technology for input or remedial evaluation procedure.	No standard method exists. See model of remedial technology for input or remedial evaluation procedure.	
Enumeration	Special procedures must be followed to collect subsurface solids samples for laboratory study that are not contaminated by microbiota from other sources.	Major types of methods include cultures, microscopic, chemical and radioisotope analyses (Ghiorse and Wilson, 1988; Page et al. 1982, chapters 37 to 40; Poindexter and Ledbetter, 1986).	
Macrofauna and Mesofauna	Record visual sighting of animals, evidence of habitation, tracks, feeding remains, distribution and number of burrows with reference to source and extent of contamination.	Methods for distribution and diversity of mesofauna (Wallwork, 1976). Mites and other arthropods (Woolley, 1982)	Consult area biologists on possible presence of endangered species. Enumerate numbers, distribution, and kinds of macro- and mesofauna. Consult literature for macro- and mesofauna for site and soil moisture and thermic regimes.
Microbiota	Record field observations of microbial surface crusts, especially algal-lichen soil crusts, mold growth, and evidence of decay.	Soil enzymes (Tabatabai, 1982). Filamentous fungi (Parkinson and Paul, 1982). Actinomycetes (Wellington, 1982). Anaerobic bacteria and processes (Kaspar and Tiedje, 1982). Soil bacteria (Allen, 1957). Algae (Shields, 1982). Protozoa (Stout et al, 1982).	Enumerate numbers, kinds, metabolisms and distribution of various microbiota. Consult literature for microbiota for site and soil moisture and thermic regimes.

# METHODS FOR DETERMINATION OF SITE AND SOIL PARAMETERS, Continued

SOIL PARAMETER	FIELD DETERMINATION	LABORATORY METHOD	CALCULATION/LOOKUP
22. SOIL POLLUTION SITUATION	Collection of field samples at depth and locations specified in the sampling plans using equipment and procedures specified in the soil sampling protocol. Odor may serve as an indicator of the presence of organic contaminants.	Analysis for all constituents that are suspected of possibly being present at the site.	Any records related to type and handling of wastes should be checked in developing the list of constituents of concern and in choosing sampling locations.
Toxicity	Qualitative observations of toxic effects of contaminants on plants and aquatic organisms may be observable.	If adequate published data are not available, laboratory toxicity methods may be required. Norton et al. (1988) describe available methods.	Norton et al. (1988) and ERG (1991) discuss various approaches to evaluate toxicity risk for ecological systems.
Reactivity	The known or possible presence of reactive hazardous materials may require use of respirators and special protective gear while sampling.		
Corrosivity	Field sampling of waste to measure determine corrosivity may be required.		
Ignitability			
Contaminant General Chemical Properties	Not applicable.	Laboratory methods will generally not be required unless standard reference books do not contain the desired data.	See below for source for specific parameters.
Chemical Class	Not applicable.		Various standard chemical reference sources available.
Solubility/Miscibility in Water	Not applicable.		Water solubility can be estimated from KOW (octanol/water partition coefficient), see Chapter 2 in Lyman et al. (1990).
Speciation	Not applicable.	See soil chemistry parameters: redox potential, clay mineralogy, other mineralogy, salinity, and sodicity.	Phases and species in aqueous systems under various geochemical conditions can be estimated using distribution-of-species geochemical models (U.S. EPA, 1990b, chapter 5).

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16. ABSTRACT <p>This guide is intended to assist field personnel who must identify, describe, and interpret site and soil characteristics of hazardous waste sites where metals contamination is suspected or known. The approach presented, including the knowledge frames of an expert system, will be unfamiliar to most site investigators. For developers of expert systems, the Guide should facilitate standardization of questions and responses related to soil contamination problems.</p> <p>This guide provides a general discussion (Section 2) of the elements of a background review and an on-site examination of site and soil characteristics essential to meeting the needs of these different data uses. This general discussion is followed by a catalogue of individual site (Section 3) and soil (Section 4) characteristics (e.g., climate and weather, texture and structure, hydraulic conductivity, slope, soil microorganisms) that should be investigated during site characterization. For each entry, the guide describes possible conditions of the characteristic (e.g., high, moderate, or low; prominent, distinct, or faint) and methods for assigning these conditions. References that provide more detailed information are given for each characteristic. Extensive definitions are provided for describing contaminated sites and soils.</p> <p>Supplemental information with site characterization data; a soil description form; and a summary of methods useful for determination of site and soil parameters accompanies Volume 1 and is available in "A Pocket Field Guide".</p>					
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